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The David Dunlap Observatory

By PETER M. MILLMAN

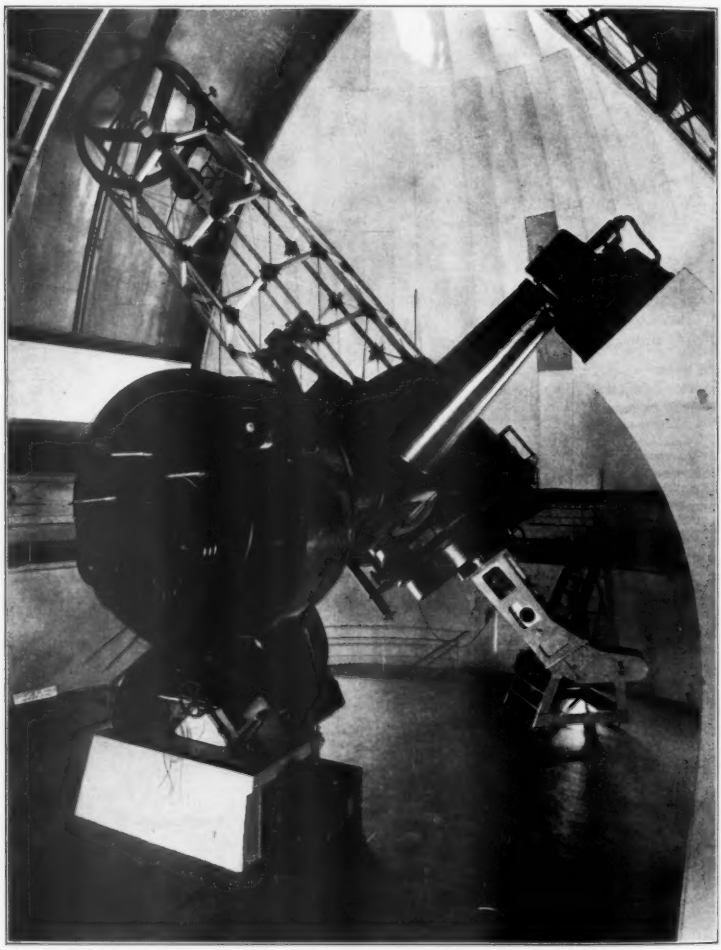
The official opening of the David Dunlap Observatory on May 31, 1935, marked the dedication to astronomical research of Canada's first large university observatory and added yet another name to the already imposing list of observatories on this continent which are the result of private benefaction. The David Dunlap Observatory was presented to the University of Toronto by Mrs. Jessie D. Dunlap in memory of her husband who, for some time previous to his death in 1924, had been much interested in the project of a great observatory for Toronto. The opening took place on the seventieth birthday of Professor C. A. Chant, for over thirty years head of the Department of Astronomy at the University of Toronto and the Dunlap Observatory's first director. Professor Chant had for many years pointed out the need of a good research observatory in Toronto and he it was who first interested Mr. D. A. Dunlap in this undertaking. Its ultimate completion was, for Professor Chant, the fulfilment of a dream of long standing.

The observatory itself is located about fifteen miles north of Toronto at the summit of a gentle rise, the elevation being 800 feet above sea level. The surrounding country is at present rolling farm land but the observatory is well protected against the encroachment of future buildings by an estate of 180 acres. This will eventually be devloped into the David Dunlap Memorial Park. The administration building of the observatory is of white stone and contains offices, library, machine shop, and laboratories. It is surmounted by three copper covered domes, the southern one of which contains a 19-inch reflector constructed by Professor R. K. Young. The main mirror of this instrument is of Pyrex and both primary and secondary have been aluminized. The other two domes are at present empty but it is hoped eventually to add a refractor of about 12-inch aperture and some rapid photographic telescopes to the observatory's present equipment.

Some fifty yards north of the administration building is the 61-foot dome. This is a steel structure and houses the 74-inch reflector designed and constructed by Sir Howard Grubb, Parsons and Co. of England. The large mirror is a disk of Pyrex just over 76 inches in diameter which was cast by the Corning Co., New York, on June 21, 1933. It was at the time the largest single piece of glass cast on this continent and the largest piece of Pyrex ever cast. Since then the Corning Co. has successfully cast the 84-inch disk for the McDonald Observatory in

Texas, and the 120-inch and two 200-inch disks for the great observatory to be erected on Mt. Palomar.

The glass for the 74-inch was ground and figured in England by the Parsons Co. The laboratory Hartmann tests of the focus for various



THE 74-INCH REFLECTING TELESCOPE

zones of the mirror yielded a Hartmann criterion T of just over 0.20, indicating a figure of very excellent quality. In fact, if the outer two inches of the mirror are omitted, T falls definitely below 0.20.

The mounting of the 74-inch is of the standard English type and is very similar to that of the 72-inch telescope at Victoria. Innovations are: an iris diaphragm 74 inches in diameter which is located just above the great mirror, making it possible to stop down the aperture; duralumin construction for the frame-work of the telescope tube; a motor for focussing the Cassegrain mirror; and a new form of mounting for the observing platform for use when working at the Newtonian focus. The telescope is driven by the improved Grubb drive. In this case a small beater, actuated by a master pendulum clock, beats once a second into V-shaped notches on a rotating disk connected with the large driving clock. If this clock is running at the correct sidereal rate the disk, which contains 24 notches, makes one revolution in exactly 24 sidereal seconds. Any variation from this rate is corrected by the beater. An electrically wound weight supplies the motive power for the driving clock but it is likely that a synchronous motor drive will be installed in the near future.

The two secondary mirrors of the 74-inch have been aluminized through the courtesy of the California Institute of Technology. It is hoped eventually to have the large mirror aluminized but no provision has been made for this as yet. The silvering of the 74-inch mirror is carried out in the silvering room which is located on the ground level directly below the observing floor and just to the east of the concrete piers on which the telescope is mounted. The mirror and its cell, a total weight of over four tons, are transferred to the silvering room by means of an elevator which runs in a vertical shaft extending to a depth of 25 feet below the ground level. For stability, the telescope piers also extend to this depth.

Because of the importance of spectrographic investigations carried out with the world's largest reflectors, a good spectrograph is one of the most essential parts of such a telescope's accessories. The 74-inch at the Dunlap Observatory is equipped with a Hilger single prism spectrograph and cameras of 25 and 13-inch focal lengths which give dispersions at $H\gamma$ of 33 and 64 angstroms per mm, respectively. This spectrograph is also designed to accommodate a 6-inch camera. The spectrograph has proved to be of the very highest quality, the 25-inch camera having an exceptionally flat field and resolving the close iron doublet at 4250 in both stellar and comparison spectra. More complete descriptions of both telescopes and spectrograph will be found in the *Journal of the Royal Astronomical Society of Canada* for 1934, 1935, and 1936.

The Dunlap Observatory is under the administration of the Department of Astronomy at the University of Toronto. Though Professor Chant is now retired he is still closely associated with the observatory as Director Emeritus, Honorary Librarian, and Director of Publications. The present director of the observatory is Professor R. K. Young who, together with Professor Chant, had immediate supervision over the planning and construction of the telescope and buildings. The observing

staff consists, in addition, of Dr. F. S. Hogg, Dr. J. F. Heard, and the writer. Miss R. J. Northcott is computer and Miss E. M. Fuller, secretary and librarian.

The first plates were taken with the 74-inch on the evening of June 9, 1935. Much of the summer was taken up in adjusting the polar axis and the driving mechanism and in putting the telescope in efficient working order. Though the winter weather in the neighborhood of Toronto is extremely unfavorable for any type of observational work over 750 plates had been secured up to the middle of April, 1936. The majority of these are spectrograms of stars between magnitudes 6.0 and 7.5 in and near the Kapteyn standard regions north of the equator. The observatory is at present engaged in a general radial velocity program including all stars brighter than magnitude 7.5 which are within 2 degrees of the centers of the northern Kapteyn regions and which have

THE DAVID DUNLAP OBSERVATORY

not been observed elsewhere. Various spectroscopic binaries are also being studied by the staff in connection with individual programs of investigation. Dr. F. S. Hogg and Dr. Helen Sawyer Hogg have secured a number of direct photographs at the Newtonian focus of the 74-inch in connection with the study by Mrs. Hogg of the variable stars in distant globular clusters. Mrs. Hogg expects to continue this investigation. Since the autumn of 1933 the Dunlap Observatory has also served as headquarters for programs of visual and photographic observation of meteors in various parts of Canada and more particularly in Ontario.

While a large reflector is essentially a photographic instrument and hence extremely disappointing when used visually, the 74-inch is equipped with a visual eyepiece and arrangements have been made whereby the public may have an opportunity of observing with it. At the present time the observatory is open to the public from 8:00 to 10:00 on Saturday evenings. If the weather permits, the great telescope is adjusted for visual work and is directed to some object of interest. In addition to this, visitors are shown the buildings and instruments on certain afternoons of the week. With the exception of the visiting hours on Saturday evening the telescope is in constant use as a

photographic instrument on all clear nights.

The telescope of the Dunlap Observatory has proved efficient in every way, even under the rigours of winter observation which, during the past season, was often carried out when the temperature in the dome was well below zero. All those interested in the rapid advancement of our scientific knowledge, and astronomers in particular, owe a big debt of gratitude to Mrs. Dunlap for her most magnificent gift which will stand as an ever-living monument of international significance to the memory of David Alexander Dunlap.

The Lunar Saros Series of the Columbus Eclipse of 1504 February 29-March 1

By ALEXANDER POGO

The study of a lunar saros series is, essentially, a study of the gradual evolution of the spherical triangle formed by the node, the center of the earth's shadow, and the center of the disk of the full moon. While the saros series progresses, this triangle moves eastward along the ecliptic, at the average rate of 10.8 degrees per saros; the relative westward motion, with respect to the node, carries both the shadow and the full moon from their greatest eastern to their greatest western elongation, causing the triangle first to shrink, then to expand. In Figure 1, the upper sketches refer to an ascending-node saros series, the lower, to a descending-node series; the relative sizes of the circle representing the moon's disk and of the two concentric circles representing the cross-section of the umbral and of the penumbral cones by the plane of the moon's disk correspond to average values; in any given lunar saros series, these three circles vary gradually in size; for the sake of generality, and on account of the small scale of the sketches, these gradual changes are not shown in Figure 1; the moon's disk is at its maximum when the moon is in perigee; the width of the penumbra—equal to the diameter of the sun's disk—is at its maximum, when the earth is in perihelion; the smallest lunar disk and the narrowest penumbra correspond to apogee and aphelion, respectively.

If the moon happens to be in perigee, the earth in perihelion, and the angle between the planes of the orbits of the moon and of the earth at its minimum, the moon may touch the penumbra when the center of the shadow is 18° 28′ east of the node; such a theoretical contact at the major penumbral ecliptic limit is, of course, of no practical value; its significance, from the point of view of eclipse statistics, lies in the fact —hitherto neglected by the few writers who took the trouble of investigating lunar appulses—that it correlates the values of the lunar and solar major penumbral limits (the latter is usually given as 18° 31′, and corresponds to the use of slightly different limiting values of the semidiameters of the sun and of the moon, and of the equatorial horizontal

parallax of the moon). If the inclination of the moon's orbit happens to be at its maximum, in case of a full moon at perigee and perihelion, the theoretical contact with the penumbra could occur when the center of the shadow is 17° 22′ east of the node.

If the moon happens to be in apogee, the earth in aphelion, and the inclination of the moon's orbit at its maximum, the moon may graze the penumbra when the center of the shadow is 15° 23′ east of the node, at the minor penumbral limit; the theoretical importance of such an un-

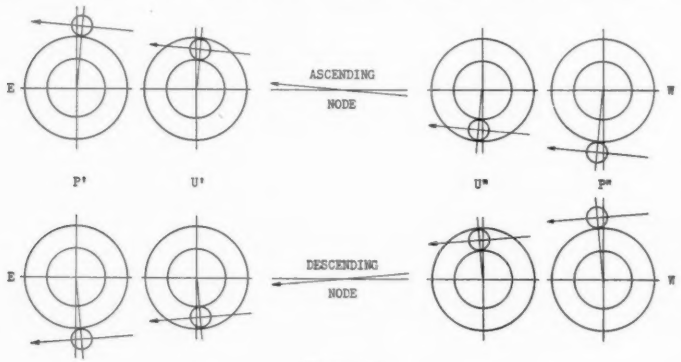


FIGURE 1
LUNAR ECLIPTIC LIMITS.

observable contact is due to the fact that it establishes a correlation between the values of the lunar and solar minor penumbral limits (the latter is usually given as 15° 21′). If the inclination of the moon's orbit happens to be at its minimum, in the case of a full moon at apogee and aphelion, the contact with the penumbra may occur when the eastern elongation of the shadow is 16° 23′.

For all the other positions of the full moon and of the earth in their respective orbits, and for the intermediate values of the mutual inclination of these orbits, the first penumbral eclipse of a lunar saros series may occur when the center of the shadow is from 18° 28′ to 15° 23′ east of the node; the first penumbral eclipse of the series will be, as a rule, an encroachment of the moon's disk on the penumbra, not a mere con-

TABLE I

LUNAR ECLIPTIC LIMITS

Limits	$\lambda_{moon}-\lambda_{node}$ (regardless of sign)				——Orbital data——		
	At opposition		At mid-eclipse				
	Geom. shad.	Phys. shad.	Geom. shad.	Phys. shad.	Moon	Earth	Incl.
Major penumbral	18°28′	18°49′	18°20′	18°41′	Perigee	Perihelion	min.
Minor "	15°23′	15°40′	15°15′	15°32′	Apogee	Aphelion	max.
Major umbral	12° 4′	12°14′	11°59′	12° 9′	Perigee	Aphelion	min.
Minor "	9°30′	9°35′	9°25′	9°30′	Apogee	Perihelion	max.

tact. As the saros series progresses from P′ to U′ in our Figure 1, the gradual shrinking of our spherical triangle brings the shadow closer to the node, and the moon closer to the umbra. The number of penumbral eclipses in the initial run of a given saros series depends on the region of the ecliptic through which our spherical triangle is carried eastward by the succession of saros intervals. If the dates of the penumbral

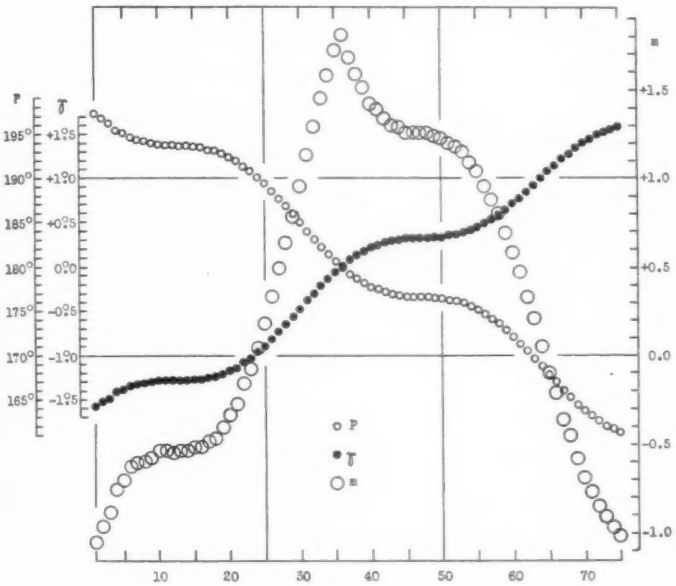


FIGURE 2

THE ELEMENTS P AND γ, AND THE MAGNITUDES OF THE LUNAR SAROS SERIES L24.

eclipses of an initial run belong to summer months, the number of appulses may be as low as 6; if, on the other hand, the initial run is carried through the winter months, the distance between the shadow and the node decreases very slowly, and the number of appulses preceding the first partial eclipse of the series may exceed 20: the seasonal

TABLE II

LIMITING LATITUDES OF THE ECLIPSED MOON

Limits	At opposition		At mid-eclipse		Orbital data	
	Geom. shad.	Phys. shad.	Geom. shad.	Phys. shad.	Moon	Earth
Major penumbral	1°35′	1°37′	1°34′	1°36′	Perigee	Perihelion
Minor "	1°25′	1°26′	1°24′	1°25′	Apogee	Aphelion
Major umbral	1° 3′	1° 4′	1° 2′	1° 3′	Perigee	Aphelion
Minor "	0°53′	0°53′	0°52′	0°53′	Apogee	Perihelion

variations of the rate of shrinking of the spherical triangle will be discussed below. When the distance between the limb of the moon and the umbra becomes sufficiently small, the appulse becomes plainly visible to the naked eye; in a forthcoming paper, the appulse of 1936 December 28 will be discussed—the 14th initial penumbral eclipse of the lunar saros series L25, an appulse visible to the naked eye, and separated by 6 saros intervals from the first partial eclipse of the series, 2045 March 3.

The gradual shrinking of our spherical triangle brings the shadow and the full moon to a relative position shown in the sketches marked U′ in our Figure 1. If, at the end of the initial penumbral run, the moon should happen to be in perigee, the earth in aphelion, and the inclination at its minimum, the moon would graze the umbra when the center of the shadow is 12° 4′ east of the node, at the major umbral limit. If the inclination of the moon's orbit happens to be at its maximum, in the case of a full moon at perigee and aphelion, the contact with the umbra may occur when the center of the latter is 11° 20′ east of the node; for the same apsidal positions of the moon and of the earth in their respective orbits, with an average mutual inclination of these orbits, the distance would be 11° 45′; for solar eclipses, the usually quoted value of the major umbral limit is 11° 50′.

If the end of the initial run should find the moon in apogee, the earth in perihelion, and the inclination at its maximum, the contact of the moon with the umbra would occur when the center of the latter is 9° 30′ east of the node, at the minor umbral limit. If the inclination of the moon's orbit happens to be at its minimum, for the same apsidal positions of the moon and of the earth, the contact with the umbra would occur when the eastern elongation of the shadow is 10° 10′; for the average inclination, the corresponding limit would be 9° 55′; for solar eclipses, the usually quoted value of the minor umbral limit is 9° 55′.

In the majority of lunar saros series, the initial penumbral run will end when the moon and the earth are not crossing the lines of apsides of their respective orbits, and when the mutual inclination of these orbits has values differing from the maximum, the minimum, or the average. The first umbral eclipse of the series will, therefore, occur when the longitude of the full moon exceeds the longitude of the node by less than 12° 4′, but more than 9° 30′; moreover, the first umbral eclipse of the series will be, in general, an encroachment of the moon on the umbral cone, not a mere contact with it.

As the saros series proceeds, the spherical triangle continues to shrink, the umbral eclipses pass through the initial run of partial eclipses, then become total. Since total eclipses of the moon are adequately treated in textbooks which fail to mention penumbral lunar eclipses, we shall not insist on the conditions prevailing between the major and the minor total ecliptic limits. The spherical triangle continues to shrink, until it disappears; then it reappears west of the node, and its gradual expansion leads to a similar sequence of events; see the

sketches U″ and P″ of Figure 1. The values of the various theoretical limits west of the node are, of course, the same as the corresponding values of the limits mentioned in the preceding paragraphs; in a given saros series, however, the numbers of penumbral, partial, and total eclipses occurring west of the node differ from the numbers of corresponding eclipses which occurred east of the node.

In computing the lunar ecliptic limits discussed in the previous paragraphs, I have used the diameters of the geometrical umbra and penumbra—in other words, I have neglected the influence of the earth's atmosphere on the actual size of the two concentric circles of the sketches of Figure 1. Observation shows that the actual or physical umbra extends beyond the limits of the geometrical umbra; Oppolzer[1] adopted, for the width of this umbral fringe, 1/40 of the semidiameter of the geometrical umbra: modern nautical almanacs adopt the value 1/50. Since small penumbral eclipses are quite invisible, the existence of a similar penumbral fringe cannot, of course, be proved by observation; it is even possible to postulate that the physical penumbra is smaller than the geometrical penumbra, by assuming that the umbral fringe is due to a shrinking of the umbral cone at its solar basis rather than to a widening of its terrestrial cross-section.[2] The nautical almanacs adopt a 2-per cent increase of the semidiameter of the penumbra, as is shown by the "moon enters penumbra" and "moon leaves penumbra" predictions included, for the sake of completeness, in the published tabulations of the observable circumstances of partial and total lunar eclipses. If we adopt 2 per cent of the corresponding semidiameters for the width of the fringes surrounding the geometrical umbra and the geometrical penumbra, we obtain the increased values of the lunar ecliptic limits listed in the second column of Table I.

The values given in Tables I and II require a few remarks concerning the longitudes of the shadow and of the moon, and the latitudes of the moon. If the center of the moon happens to cross the ecliptic exactly at the node, the middle of the resulting total lunar eclipse occurs, of course, at the moment of opposition in longitude. In the overwhelming majority of total lunar eclipses—and in the case of all the partial and of all the penumbral eclipses of the moon—the moment of closest approach does not coincide with the moment of opposition in longitude; this is clearly illustrated by the sketches of Figure 1. If the moon crosses the ecliptic east of the node, the middle of the eclipse precedes the moment of opposition in longitude; west of the node, the moon is full before the maximum phase is reached. In the case of total eclipses of short duration, the difference between the moment of opposition in longitude and the moment of maximum phase may reach 5 minutes; in the case of partial eclipses, the difference varies between 4 and 11 minutes; for

[1] Denkschriften d. Akademie, math.-naturw. Cl., 52, pag. XXXII, Wien 1887.

[2] E. Mora, L'ombre de la terre dans les éclipses de lune. *Bulletin de la Soc. astr. de France*, 50, 89-92, 1936.

penumbral eclipses, it varies between 9 and 18 minutes. Let us see how these differences of time affect the coördinates of the shadow and of the moon, and, therefore, the limiting values given in Tables I and II.

As far as the longitude of the center of the shadow is concerned, it is practically the same at full moon and at mid-eclipse, due to the slow daily motion of the sun; even in 18 minutes, the change in the distance between the shadow and the node cannot exceed 46″. It is, therefore, permissible to neglect the distinction between the distance of the center of the shadow from the node at the moment of maximum phase, on the one hand, and the distance of the center of the shadow from the node at the moment of opposition in longitude, on the other. As far as the geocentric longitude of the center of the moon is concerned, the changes are more conspicuous, due to the rapid motion of that body in its orbit; see the third and fourth columns of Table I. The various canons of umbral lunar eclipses and the writer's list[3] of penumbral lunar eclipses give the moment of maximum phase, not of opposition in longitude,—and take, of course, into consideration the presence of the shadow fringes. The values included in Table III are taken from the fourth column of Table I.

Is a partial lunar eclipse possible, if the geocentric latitude of the full moon exceeds the semidiameter of the physical umbra? Is a penumbral lunar eclipse possible, if the geocentric latitude of the full moon exceeds the semidiameter of the physical penumbra? The affirmative answer to these two questions is illustrated by the sketches of Figure 1. The distance of the moon from the ecliptic at the moment of opposition in longitude is always slightly larger than its distance from the ecliptic at the moment of closest approach to the shadow; the difference in latitude amounts to about 0′.5 for limiting umbral eclipses, and to about 0′.7 for limiting penumbral eclipses; in the case of investigations dealing with the numbers of partial and penumbral eclipses in lunar saros series, this difference in latitude cannot be neglected. The values of the fourth column of Table II are included in the data of Table III.

TABLE III

LUNAR MID-ECLIPSE CRITERIA

(Physical shadow, 2 p.c. fringes)

Penumbral impossible	$\lvert\lambda_m-\lambda_n\rvert>18°41'$	$\lvert\beta\rvert>1°36'$
Penumbral possible	$18°41'>\lvert\lambda_m-\lambda_n\rvert>15°32'$	$1°36'>\lvert\beta\rvert>1°25'$
Penumbral certain	$15°32'>\lvert\lambda_m-\lambda_n\rvert>12°\ 9'$	$1°25'>\lvert\beta\rvert>1°\ 3'$
Penumbral certain, partial possible	$12°\ 9'>\lvert\lambda_m-\lambda_n\rvert>\ 9°30'$	$1°\ 3'>\lvert\beta\rvert>0°53'$
Partial certain	$9°30'>\lvert\lambda_m-\lambda_n\rvert>\ 5°43'$	$0°53'>\lvert\beta\rvert>0°30'$
Partial certain, total possible	$5°43'>\lvert\lambda_m-\lambda_n\rvert>\ 4°\ 8'$	$0°30'>\lvert\beta\rvert>0°23'$
Total certain	$4°\ 8'>\lvert\lambda_m-\lambda_n\rvert$	$0°23'>\lvert\beta\rvert$

[3] A list of penumbral eclipses of the moon visible in the Maya territory between 500 B.C. and A.D. 1500; it will be published elsewhere.

In addition to the criteria given in Table III and based on the geocentric coördinates of the moon at the moment of maximum phase, we have another means of determining the class to which a lunar eclipse belongs—its magnitude. The positive magnitudes given in Table IV measure the depth of immersion into the physical umbra, and are familiar to the users of modern nautical almanacs; they supersede the antiquated system using a duodecimal subdivision of the moon's diameter—and decimal fractions of these duodecimals. The magnitude of a penumbral eclipse could be expressed by measuring the depth of immersion of the moon into the physical penumbra; this would, however, lead to a discontinuity in the scale of magnitudes. The negative

TABLE IV

MAGNITUDES OF LUNAR ECLIPSES
(Moon's diameter = 1.0)

Eclipses	Maximum phase
Total	+1.0 to +1.9
Partial	0.0 to +1.0
Penumbral	−1.1 to 0.0

magnitudes given in Table IV measure the distance between the moon's limb and the physical umbra at the moment of maximum phase, thus establishing a continuity of scale; when the distance is zero, we have the limiting case of a partial eclipse of magnitude 0.0; when the distance is negative, we have encroachment of the moon on the umbra, i.e., an umbral eclipse, and the corresponding magnitude is positive.

Let us turn to Table V; it gives the essential elements and circumstances of the eclipses of the lunar saros series L24, computed with the aid of P. V. Neugebauer's ecliptic tables.[4] The results of these computations were compared, as far as the umbral eclipses are concerned, with the corresponding data in Oppolzer's lunar *Canon*[5] and in Schroeter's *Spezieller Kanon*;[6] the terminal appulse data of Table V were compared with the corresponding data obtained, both by graphic construction and by purely computational means, from nautical almanacs; moreover, the longitudes of the node and the geocentric ecliptic coördinates

[4] Astronomische Chronologie. 2 vols. Berlin 1929. Neugebauer's ecliptic tables are based on Schram's *Tafeln zur Berechnung der näheren Umstände der Sonnenfinsternisse* (Denkschriften d. Akademie, 51, Wien 1886) and on Schoch's *Verbesserung der Schramschen Sonnenfinsternis-Tafeln* (Sirius, 59, 274-78, 1926). Neugebauer's ecliptic tables were not intended for the computation of lunar appulses, and it was, occasionally, necessary to form the arguments missing in his tables of periods by combining the arguments of tables E69 and E90.

[5] Denkschriften d. Akademie, 52, Wien 1887. Oppolzer calls, on page XXXI, attention to the fact that his lunar *Canon* is based on his *Tafeln zur Berechnung der Mondesfinsternisse* (Denkschr. d. Akad., 47, Wien 1883); for this, and for several other reasons, the data of Oppolzer's lunar *Canon* are less reliable than the data of his solar *Canon* which is based on his elaborate *Syzygien-Tafeln für den Mond* (Publ. d. astr. Gesellschaft, 16, Leipzig 1881).

[6] Spezieller Kanon der zentralen Sonnen-und Mondfinsternisse. Kristiania 1923.

TABLE V

LUNAR SAROS SERIES L24.

		Date	GCT	J.D. GMT	Magn.	λ_z	ϕ_z	P	L	γ
			h m			°	°	°	°	
1	a	548 Aug 5	10 50	1921 431.95	−1.06	−161	−17	197.3	314.3	−1.38
2	a	566 Aug 16	18 1	28 017.25	−0.97	+ 91	−14	196.7	324.9	−1.53
3	a	584 Aug 27	1 21	34 602.56	−0.89	− 20	−10	196.2	335.6	−1.49
4	a	602 Sep 7	8 41	41 187.86	−0.76	−131	− 5	195.4	346.4	−1.47
5	a	620 Sep 17	16 11	47 773.17	−0.71	+116	− 1	195.1	357.3	−1.39
6	a	638 Sep 28	23 51	54 358.49	−0.63	0	+ 3	194.6	8.1	−1.35
7	a	656 Oct 9	7 39	60 943.82	−0.61	−118	+ 8	194.3	19.0	−1.33
8	a	674 Oct 20	15 35	67 529.15	−0.60	+122	+12	194.2	30.0	−1.32
9	a	692 Oct 30	23 36	74 114.48	−0.58	+ 2	+15	194.0	41.1	−1.31
10	a	710 Nov 11	7 37	80 699.82	−0.54	−118	+18	193.8	52.2	−1.29
11	a	728 Nov 21	15 49	87 285.16	−0.54	+120	+21	193.7	63.4	−1.29
12	a	746 Dec 2	23 58	93 870.50	−0.55	− 2	+22	193.8	74.5	−1.29
13	a	764 Dec 13	8 8	2000 455.84	−0.54	−123	+24	193.7	85.7	−1.29
14	a	782 Dec 24	16 17	07 041.18	−0.54	+116	+23	193.7	96.8	−1.29
15	a	801 Jan 4	0 23	13 626.52	−0.52	− 4	+22	193.6	108.0	−1.28
16	a	819 Jan 15	8 28	20 211.85	−0.52	−124	+20	193.5	119.3	−1.28
17	a	837 Jan 25	16 24	26 797.18	−0.49	+117	+18	193.2	130.4	−1.26
18	a	855 Feb 6	0 9	33 382.51	−0.47	+ 1	+15	193.1	141.4	−1.25
19	a	873 Feb 16	7 43	39 967.82	−0.41	−112	+11	192.8	152.3	−1.22
20	a	891 Feb 27	15 12	46 553.13	−0.34	+135	+ 7	192.3	163.2	−1.18
21	a	909 Mar 9	22 29	53 138.44	−0.28	+ 25	+ 2	192.0	174.0	−1.15
22	a	927 Mar 21	5 42	59 723.74	−0.16	− 84	− 2	191.3	184.8	−1.08
23	a	945 Mar 31	12 43	66 309.03	−0.08	+170	− 6	190.8	195.5	−1.04
24	p	963 Apr 11	19 34	72 894.32	+0.04	+ 67	−10	190.1	206.1	−0.97
25	p	981 Apr 22	2 22	79 479.60	+0.18	− 36	−14	189.4	216.6	−0.90
26	p	999 May 3	8 53	86 064.87	+0.33	−134	−17	188.5	227.1	−0.82
27	p	1017 May 13	15 26	92 650.14	+0.49	+127	−20	187.6	237.6	−0.73
28	p	1035 May 24	21 54	99 235.41	+0.63	+ 31	−22	186.8	248.2	−0.65
29	p	1053 Jne 4	4 23	2105 820.68	+0.78	− 66	−23	185.9	258.5	−0.57
30	p	1071 Jne 15	10 45	12 405.95	+0.95	−161	−24	185.0	268.9	−0.48
31	t	1089 Jne 25	17 10	18 991.22	+1.13	+103	−23	184.0	279.3	−0.38
32	t	1107 Jul 6	23 36	25 576.48	+1.29	+ 7	−22	183.1	289.8	−0.30
33	t	1125 Jul 17	6 7	32 161.75	+1.45	− 90	−20	182.2	300.1	−0.21
34	t	1143 Jul 28	12 44	38 747.03	+1.58	+171	−18	181.4	310.6	−0.14
35	t	1161 Aug 7	19 26	45 332.31	+1.72	+ 70	−15	180.6	321.1	−0.06
36	t	1179 Aug 19	2 18	51 917.60	+1.81	− 34	−11	179.9	331.7	+0.01
37	t	1197 Aug 29	9 18	58 502.89	+1.68	−140	− 7	179.2	342.3	+0.08
38	t	1215 Sep 9	16 25	65 088.18	+1.59	+113	− 3	178.7	353.1	+0.13
39	t	1233 Sep 19	23 47	71 673.49	+1.51	+ 1	+ 2	178.2	3.9	+0.17
40	t	1251 Oct 1	7 17	78 258.80	+1.42	−112	+ 6	177.7	14.7	+0.22
41	t	1269 Oct 11	15 1	84 844.13	+1.39	+131	+10	177.5	25.7	+0.24
42	t	1287 Oct 22	22 48	91 429.45	+1.34	+ 14	+14	177.2	36.7	+0.27
43	t	1305 Nov 2	6 44	98 014.78	+1.30	−105	+17	176.9	47.7	+0.29
44	t	1323 Nov 13	14 51	2204 600.12	+1.29	+134	+20	176.8	58.8	+0.30
45	t	1341 Nov 23	23 3	11 185.46	+1.26	+ 12	+22	176.6	70.0	+0.32
46	t	1359 Dec 5	7 16	17 770.80	+1.26	−110	+23	176.6	81.2	+0.32
47	t	1377 Dec 15	15 34	24 356.15	+1.26	+126	+24	176.6	92.3	+0.32
48	t	1395 Dec 26	23 52	30 941.49	+1.26	+ 3	+23	176.6	103.5	+0.32
49	t	1414 Jan 6	8 13	37 526.84	+1.24	−121	+21	176.5	114.7	+0.33
50	t	1432 Jan 17	16 26	44 112.18	+1.23	+117	+19	176.4	125.9	+0.33
51	t	1450 Jan 28	0 38	50 697.53	+1.20	− 6	+16	176.2	137.0	+0.35
52	t	1468 Feb 8	8 45	57 282.86	+1.18	−128	+13	176.1	148.2	+0.36
53	t	1486 Feb 18	16 45	63 868.20	+1.15	+112	+ 8	175.9	159.1	+0.38
54	t	1504 Mar 1	0 41	70 453.53	+1.09	− 8	+ 4	175.5	170.0	+0.41
55	t	1522 Mar 12	8 27	77 038.85	+1.04	−125	0	175.1	180.8	+0.44
56	p	1540 Mar 22	16 8	83 624.17	+0.95	+119	− 5	174.6	191.6	+0.49
57	p	1558 Apr 2	23 40	90 209.49	+0.88	+ 5	− 9	174.1	202.4	+0.53
58	p	1576 Apr 13	7 6	96 794.80	+0.80	−107	−13	173.6	213.0	+0.58

		Date	GCT h m	J.D. GMT	Magn.	λ_s °	ϕ_s °	P °	L °	γ
59	p	1594 May 4	14 28	2303 380.10	+0.69	+142	−16	172.9	223.6	+0.64
60	p	1612 May 14	21 48	09 965.41	+0.58	+ 32	−19	172.1	234.1	+0.71
61	p	1630 May 26	5 3	16 550.71	+0.47	− 76	−21	171.3	244.6	+0.77
62	p	1648 Jne 5	12 15	23 136.01	+0.33	+176	−23	170.5	255.2	+0.84
63	p	1666 Jne 16	19 20	29 721.31	+0.21	+ 70	−24	169.6	265.6	+0.92
64	p	1684 Jne 27	2 31	36 306.60	+0.05	− 37	−23	168.7	276.0	+1.00
65	a	1702 Jul 9	9 44	42 891.91	−0.10	−145	−22	167.8	286.4	+1.08
66	a	1720 Jul 19	16 58	49 477.21	−0.21	+107	−21	167.0	297.0	+1.14
67	a	1738 Jul 31	0 14	56 062.51	−0.36	− 2	−18	166.0	307.5	+1.22
68	a	1756 Aug 10	7 38	62 647.82	−0.45	−113	−16	165.3	318.0	+1.27
69	a	1774 Aug 21	15 7	69 233.13	−0.58	+134	−12	164.4	328.5	+1.34
70	a	1792 Aug 31	22 45	75 818.45	−0.69	+ 19	− 8	163.8	339.1	+1.40
71	a	1810 Sep 13	6 29	82 403.77	−0.77	− 98	− 4	163.2	349.7	+1.44
72	a	1828 Sep 23	14 22	88 989.10	−0.85	+143	0	162.6	0.4	+1.49
73	a	1846 Oct 4	22 27	95 574.44	−0.91	+ 21	+ 4	162.1	11.2	+1.52
74	a	1864 Oct 15	6 30	2402 159.77	−0.97	−101	+ 9	161.8	22.1	+1.55
75	a	1882 Oct 26	14 45	08 745.11	−1.02	+135	+13	161.3	33.1	+1.58

Eclipses 1 to 58, Julian calendar; eclipses 59 to 75, Gregorian calendar.
a — penumbral eclipses (appulses); p — partial eclipses; t — total eclipses

of the moon at mid-eclipse were computed for all the penumbral eclipses and for a selected group of umbral eclipses, with the aid of either Neugebauer's lunar tables[7] or of Schoch's tables,[8] or both. A detailed discussion of the results of these comparisons—and of similar material accumulated in the course of my study of the Maya table of ecliptic syzygies in the Dresden Codex—will be published elsewhere. It will suffice, for the purposes of the present paper, to point out that the plotting of the arguments I and II and of the elements P and γ offers a simple means of checking the computations of a group of eclipses belonging to the same saros series. The curve of P-180° and the γ-curve of Figure 2 represent, with satisfactory accuracy, the elongation curve, λ-☉, and the latitude curve, β, respectively, of our descending-node saros series L24.

If we plot the differences between the successive values of L, as given in Table V, we obtain a sinusoidal increase-of-longitude curve; by plotting the differences between the successive mid-eclipse moments, we obtain a similar duration-of-the-saros curve; both curves reach their respective maxima, when the earth is in the perihelion arc of its orbit, and their respective minima, when the earth is in its aphelion arc. A glance at Figure 2 shows that the elongation, the latitude, and the magnitude curves reveal slow changes of the ordinates, when the earth is in the perihelion arc, and rapid changes, when it is in the aphelion arc. The rapid eastward motion of the shadow, in the case of winter eclipses, offsets the average saros-to-saros westward motion of the shadow with respect to the node; if the shadow happens to be east of the node, it fails to approach the node; in the case of a western elongation, the shadow

[7] Tafeln zur astronomischen Chronologie II. Leipzig 1914.
[8] Planeten-Tafeln für Jedermann. Berlin 1927.

fails to recede from it; the values of the elongation, the latitude, and the magnitude remain practically unchanged; the moon needs additional time to overtake the shadow east of the point corresponding to the average saros-to-saros eastward motion of our spherical triangle, and the duration-of-the-saros and the increase-of-longitude curves reach their winter peaks. In the case of summer eclipses, on the other hand, the slow eastward motion of the shadow enhances the average saros-to-saros westward motion of the shadow with respect to the node; successive saros returns produce a rapid decrease of the eastern elongation or a rapid increase of the western elongation of the shadow; the curves of Figure 2 reach their steepest grades; the moon saves time in overtaking the shadow west of the point corresponding to the average saros-to-saros eastward motion of the spherical triangle, and the duration-of-the-saros and the increase-of-longitude curves drop to their reduced summer values. The effects of the position of the moon in its orbit on these seasonal changes will be discussed in a separate paper, in connection with the lunar exeligmos curves; readers who have taken the trouble of watching children running against the movement of an escalator or of an automatic sidewalk will have no difficulty in following the movements of the full moon and of the shadow near the node, and the resulting deformations of our shrinking and expanding spherical triangle.

The leap-day eclipse of 1504 February 29-March 1 is traditionally connected with the name of Columbus.[9] Chinese documents[10] mention at least 21 eclipses belonging to our saros series; two of them—the eclipses of 1089 June 25 and of 1468 February 8—were "hidden by clouds" at the recording stations; designating the exeligmos curves of series L24 as Eastern Pacific, Western Pacific, and African, after the geographical location of their loops, we have the following distribution of the 21 Chinese eclipses:

E. Pacific — 1089, 1143, 1197, 1251, ... 1468, 1522;
W. Pacific — 1161, 1215, 1269, ... 1377, 1432, 1486, 1540, 1594, 1648;
African — 1017, 1071, ... 1395, 1450, ... 1612, 1666.

The first terminal appulse of the lunar saros series L24 occurred 1702 July 9; one lunation later, 1702 August 7, the first initial penumbral eclipse of series L25 took place. The last penumbral eclipse of series L24 occurred 1882 October 26; it was preceded, five lunations earlier, 1882 June 1, by the last initial appulse of series L19, and it was followed, at the interval of one lunation, 1882 November 25, by the 11th initial penumbral eclipse of series L25. This year, after the lapse of one exeligmos, the series L19 is marked by the Fourth-of-July eclipse

[9] William F. Rigge. The Columbus eclipse. POPULAR ASTRONOMY, **31**, 506-509, 1923. The twelve dates, 1702 July 8 to 1900 November 2, listed on p. 509, do not, unfortunately, correspond to full moons.

[10] Pierre Hoang. Catalogue des éclipses de soleil et de lune. Variétés sinologiques No. 56. Chang-hai 1925.

of 1936; at the syzygy of 1936 November 28, the full moon will pass north of the penumbra; and one lunation later, the full moon of series L25 will pass south of the umbra; the resulting appulse of 1936 December 28 will be the subject of a forthcoming paper.

CARNEGIE INSTITUTION
WASHINGTON, D. C.

Venus Visible Near Superior Conjunction

By H. B. CURTIS

That the planets are of considerable interest to readers of POPULAR ASTRONOMY is borne out by the fact that in each issue there appears in the contents "Planet Notes," and that in the January issue of this year there were no less than three "principal articles" on the Planets.

In Planet Notes for June, 1936, by Clifford E. Smith, in the May issue, page 266, Mr. Smith writes: "Venus will be too near the sun in apparent position to be of interest." And in the latest issue, that for June-July, in his Planet Notes for July and August, he comments: "Venus will be rather near the sun in apparent position to be of interest, since superior conjunction occurred on June 29. By the end of August, however, it will be in eastern Leo and it will set about an hour after the sun." Now on August 31, Venus will be only an hour and six minutes east of the sun and five and a half degrees south of it, so it is doubtful that on that date even the most ardent searcher for Venus would succeed in seeing it after sunset, since the angle of the ecliptic with the horizon causes zodiacal objects to be in a disadvantageous position when setting shortly after the sun, while the reverse is true six months later, in February and March.

Now when a thing is thought *too something* "to be of interest" it may for that very reason be of considerable interest. On June 11 of this year, 1936, just 18 days before Venus was to be in superior conjunction, the atmosphere was unusually clear. It was one of Lowell's "rare days in June." This writer could not resist the ever present lure of trying to see Venus in the daytime. Consulting the *Nautical Almanac* for 1936 with a feeling of hopelessness, he obtained the relative positions of the sun and Venus, seized a pair of 8-power binoculars, shaded the sun by the gable of a house and, candidly to his surprise, "picked up" Venus in "almost no time," that is, after a five or ten seconds' search. There was Venus "dancing a jig," a brilliant point of light while dandelion seeds and other less bright objects floated by, carried rapidly to the south on a brisk cool north wind. After several minutes of excited observation, lying flat on his back to make absolutely sure it was really Venus, he fixed its position by counting the shingles from the gable peak and, on deciding Venus was just off to the right of the fifth shingle, he laid the binoculars aside and peered into the bright sky

with unaided eye. It took fifteen or twenty minutes of occasional shifting position and of alternately gazing with binoculars and with the naked eye before he could make certain he saw Venus with the naked eye. It was 2:30 Eastern Standard Time, the sun being about an hour and forty minutes past meridian. Venus was west of the sun and a little south of it and only 5° away, yet visible to the naked eye!

The *Nautical Almanac* for 1936 gives the sun's right ascension for June 11 (p. 8) after making correction for time of day: $5^h\ 19^m$, and Venus' right ascension (p. 162): $4^h\ 59^m$. Their apparent angular distance apart was therefore close to 20^m of arc or otherwise expressed, about 5°, since $1° = 4^m$.

Now there are interesting comparisons between Venus' close approach to the sun near superior conjunction and its close approach near inferior conjunction as it was on September 8, 1935.* These comparisons are given in tabular form as follows:

	Near Sup. Conj. June 11, 1936	At Inferior Conj. Sept. 8, 1935
Angular distance of Venus from the sun	5°	9°
Visibility to the naked eye	Barely visible	Distinctly visible
Actual distance from the earth	161,000,000 miles	26,100,000 miles
Apparent diameter	9".72	59".1
Stellar magnitude	—3.4	—3.2
Ratio of illum'd. area to total area	0.996	0.011
Apparent area of full disc	1	38
Apparent area of illum'd. portion of disc	1	0.42

Due to the practically full phase of Venus when near superior conjunction it appeared intrinsically more brilliant through the binoculars than when near inferior conjunction since in the latter case the sun's rays hit the planet's surface more obliquely, the actual crescent form being clearly visible. The relatively dull crescent surface area at inferior conjunction is by computation only 0.42 of the nearly full brilliant surface area, yet the stellar magnitudes given in the *Nautical Almanac* in the respective positions show that for the crescent the magnitude is only 0.2 of the magnitude unit less than that of the full brilliant surface, the apparent inference to the contrary notwithstanding.

*For discussion of visibility of Venus at inferior conjunction see POPULAR ASTRONOMY for January, 1936, p. 18.

LAKE FOREST COLLEGE, LAKE FOREST, ILLINOIS, JUNE 20, 1936.

A Planetarium of New Design

By E. G. KELLER

On July 1, 1936, a twenty-foot Copernican planetarium was completed at the University of Texas. Although this instrument was opened to the public one month before its completion the average nightly attendance during this period was 150. It is hoped that a description of this planetarium may be of interest to the readers of POPULAR ASTRONOMY.

THREE BASIC ELEMENTS

The three basic elements of this instrument are: the stellar field, the solar system itself, and a comet projector. All stars, of both the northern and southern hemispheres, visible to the unaided eye are represent-

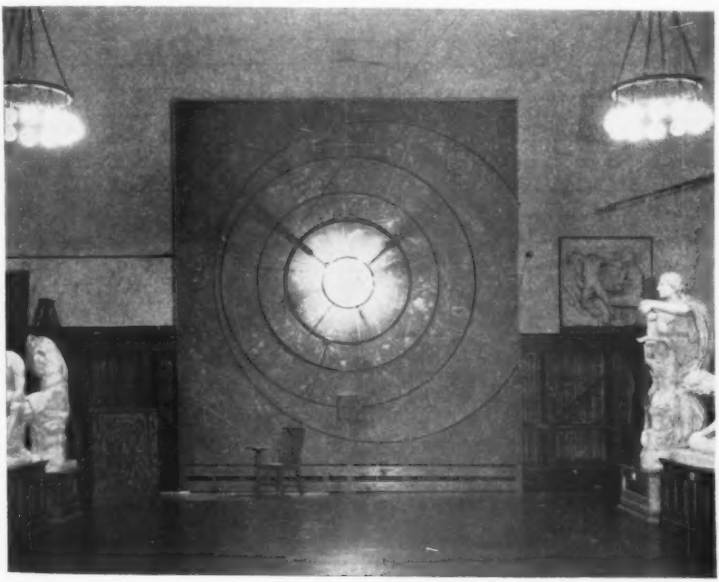


FIGURE 1
PLANETARIUM UNDER CONSTRUCTION

ed. The nine planets and twenty-six satellites of the solar system are made to scale and revolve and rotate in their correct scale periods. Comets are projected onto the plane of the ecliptic (front of the planetarium) by means of a rotating comet projector. The instrument at present has two speeds by which the year is represented in either one minute or in 20 seconds. By change of sprockets faster speeds are obtainable.

Stellar Field

The planetarium is mounted vertically and its face (shown in Fig. 1) turned toward the north represents approximately in southern latitudes the plane of the ecliptic. Some four thousand holes, varying in diameter from 1/32 to 1/4 inch, furnish, when properly illuminated and positioned, a startling representation of stars and constellations. Sixty-two 60-watt bulbs, in light-tight reflectors, emit light through these four thousand openings. All the stars of the northern and southern hemisphere can be shown at one time or merely the stars visible on any one night. The stellar field is divided into twelve sectors, one for each month, and the illumination in each sector is controlled by a separate electrical circuit. Of course, as the earth revolves around the sun only those stars which are on the side of the earth opposite the sun are visible. Since in the model the earth revolves around the sun in 20 seconds, a revolving switch causes half of the sectors to be illuminated at any time. The stars in the rotating illuminated semicircular sector represent at any instant the stars visible on some particular night. Novae of a century are represented by flash light bulbs on a low and variable voltage circuit.

The photograph in Figure 1 was taken for the Texas Centennial while the instrument was under construction. The marks depicting the constellations have been removed, the rough boards at the bottom replaced by a panel, and the instrument draped with russet velvet curtains. The statues in the photograph are awaiting removal elsewhere.

Solar System

In the model the sun is a 500-watt bulb. The planets and satellites are thin glass spheres coated with mercury. Such spheres have little mass, thus lessening wear on driving gears and they reflect brilliantly the light from the miniature sun. Jupiter is seven inches in diameter and the other planets are in proportion. The smallest spheres are clearly visible, when illuminated, at a distance of a hundred feet.

The gear boxes, which drive the satellites of the planets, run on circular tracks back of the face of the planetarium. The planets and their satellites appearing in front of the instrument are attached to rotating concentric hollow shafts which project through the circular grooves visible in Figure 1. There is one shaft for each moon and planet. The gear boxes for Jupiter and Saturn are the most complicated because each of these planets has nine moons. In both cases 7 of the 9 moons have direct motion, while two have retrograde motion about their primary. The outermost moon of Jupiter revolves in 745 days while the innermost one revolves in about 12 hours. In the model these periods of revolution correspond to 44 seconds and 1/36 of a second, respectively. To achieve this large variation in periods and also both direct and retrograde motion, six trains of five gears each were required. The gear box of Saturn is similar. The gear boxes for the Earth, Mars,

Neptune, and Uranus contain respectively 5, 7, 5, and 10 gears. Each gear box possesses its own small motor and the metal edges of the grooves act as trolley wires or third rails.

In the model the sun and all the planets, except Pluto, lie in the same plane. Pluto's orbit makes an angle of 17 degrees with the face of the planetarium. In order that the orbits of Mercury, Venus, and Earth could be constructed larger and yet the model of the solar system be contained in a 20-foot plaque, not all of Pluto's orbit is represented. When Pluto is near perihelion it projects outward from the plaque 14 inches, but when the planet is at aphelion it is on a more curved track back of the plaque. The steel band back of the face of the planetarium on which Pluto runs is not circular but a plane curve whose equation is somewhat approximately $\rho = a + b \cos \theta$, $a > b > 0$. The plane of this curve approximately bisects and makes an angle of 17 degrees with the face of the instrument.

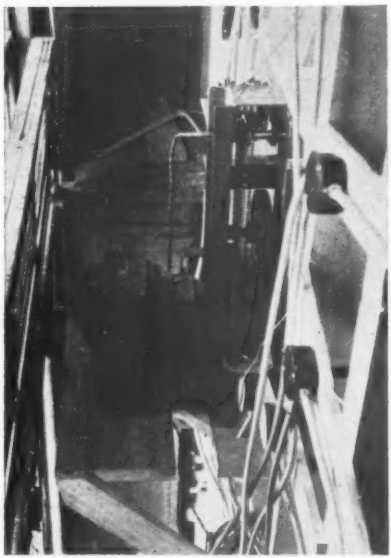


FIGURE 2
CENTRAL DRIVE OF PLANETARIUM

The motive power pulling the gear boxes along their tracks is a ¾-horsepower motor. The power is transmitted by means of gears, sprockets, and chains. Since the periods of revolution of the planets range from 5 seconds to 84 minutes, 8 gears, 14 sprockets, and 400 feet of chain are required. The central driving unit with its nest of gears and first train of sprockets is shown in Figure 2.

Comet Projector

Although the orbits of the planets are circles fixed in the face of the planetarium, it is not possible to represent so easily the orbits of comets. Comets can enter the solar system and the region of the sun from any direction. Consequently comets are projected onto the front of the planetarium. The comet projector is an optical device which projects a portion of a lantern slide of a comet in such a manner that the tail of the comet extends outward from the miniature sun as the comet traverses its orbit. It is, of course, necessary to dim the sun during the few seconds of a comet's passage.

Electrical and Mechanical Details

The motor of the central driving unit is operated from a 220-volt circuit. The gear box motors are operated on adjustable voltage ranging from 8 to 16 volts. A rheostat in each circuit controls the voltage of

Figure 3

Space between Front of Planetarium and the Frame showing Gear Boxes of Jupiter, Mars, and Earth

the small motor to give the speed required. A two-hundred-watt transformer has ample capacity for all the gear box motors. The gear boxes and their gears are made of brass while the gears of the central drive are steel. The large rotating parts are mounted on rubber and vibration noise does not exceed that of electric fans of certain manufacture.

Power is transmitted from the central drive to the sprocket shafts of the individual orbits by means of bicycle chain. The front of the planetarium is constructed of wood of an inch thickness and is enameled blue. The frame is a 20-foot plaque made of two by six inch material and strengthened by iron braces. All the weight of the central driving unit, steel orbit bands, electrical circuits, gear boxes, and planets is borne by the frame. (A portion of the space between the face and the frame of the planetarium is shown in Figure 3. The gear box for Jupiter appears near the middle of the photograph, while the boxes for Mars and Earth appear just above. The iron band carrying the gear box of Saturn is in the foreground.) Mirrors are to be installed later which will render visible to the audience the mechanism in operation. The planetarium is located in the reading room of the old library of the university and is easily visible to an audience of 500.

Cost

The instrument was designed by the writer. Neglecting also one-third of the labor cost the total expense involved was about $2,000. The labor and material costs were about equal.

Demonstrations

By dimming the sun and increasing the intensity of star illumination twilight appears. The constellations for any night of the year can be made stationary or the orderly march of the constellations from east to west across the celestial sphere can be represented by the revolving field of stars. The planets with their satellites cast strong shadows depicting eclipses. A century of motion of the planets with their moons, the advance of comets to and recession from perihelion, and the rise of the novae to brilliance and the fading to invisibility covering a period of a hundred years are shown within an hour.

Demonstrations of the planetarium, along with lectures illustrated by lantern slides, are not only a great pleasure to students and the general public, but are a stimulus to the imagination in picturing the origin, behavior, and destiny of the solar system and are an aid to the understanding of the physical universe and the reign of natural law therein.

University of Texas, July 2, 1936.

The Chicago Astronomical Society

By PHILIP FOX

The Chicago Astronomical Society held nine monthly meetings during the past season, all but the last being held in the Society's lecture room in the Adler Planetarium. The programs were as follows:

30 October 1935—"Babylonian Astronomy"—Professor A. T. Olmstead.

21 November 1935—"From Astrolabe to the Telescope—Ancient Astronomical Instruments, their Construction and Uses"—Professor Philip Fox.

18 December 1935—"The Versatility of Great Astronomers"—Professor Henry Crew.

Professor W. H. Wright attended this session and spoke informally on the work of the Lick Observatory.

24 January 1936—"General Considerations of Variable Stars"—Professor Robert H. Baker.

19 February 1936—"New Problems of Astrophysics and the MacDonald Observatory"—Professor Otto Struve. The model of the observatory built by Warner and Swasey was on exhibition at the Planetarium and gave added interest to the address.

18 March 1936—"Double Stars"—Professor Philip Fox.

22 April 1936—"The Dynamics of a Star Cluster"—Professor W. D. MacMillan.

20 May 1936—"Cosmic Rays"—Professor Arthur Compton.

24 June 1936—Meeting at the Dearborn Observatory with the unveiling of a commemorative plaque on the Meridian Circle.

This instrument had been presented to the Chicago Astronomical Society in 1869 by Mr. Walter Smith Gurnee, an early Mayor of Chicago. In the absence of the President the Vice-president, Professor D. R. Curtiss, presided. The program was as follows:

Welcome to the Observatory, by Professor O. J. Lee, Director.

Brief Review of the History of the Chicago Astronomical Society and the Dearborn Observatory and the work done with the Meridian Circle, by Professor Philip Fox.

Walter Smith Gurnee and the Unveiling of the Tablet in his honor, by Mr. Richard E. Schmidt representing Mayor Edward J. Kelly of Chicago.

In unveiling the tablet presented by the Society, Mr. Schmidt concluded with the words: "In marking this instrument with this plaque we give belated but grateful recognition to Mr. Walter Smith Gurnee, Mayor of Chicago 1851-52; a man who accepted a real opportunity to make a gift of material and lasting value to his City and for learning. May this Meridian Circle continue long in active service in fruitful research."

The May meeting was the annual meeting at which time officers for the ensuing year were elected. Messrs. Otto Struve, Oliver J. Lee, and Arthur H. Carpenter were elected Directors to replace the three whose terms had expired. Officers were elected as follows:

President	Forest R. Moulton
Vice-president	D. R. Curtiss
Treasurer	G. H. Jones
Secretary	Philip Fox

Meetings will be resumed in September for the season 1936-37.

Planet Notes for September and October, 1936

By CLIFFORD E. SMITH

Note: All times, unless otherwise stated, are Central Standard Time.

The *Sun* will be moving with an apparent southeasterly motion from central Leo to the eastern border of Virgo. It will be at the Autumnal Equinox on September 22 at $11^{d}\ 26^{m}$ P.M. This instant marks the beginning of fall. The distance from the earth to the sun will be about 93.7 million miles at the beginning of September, and this distance will decrease to about 92.2 million miles by the end of October. The position of the sun on the first day of September and the first and last days of October will be, respectively: R.A. $10^{h}\ 40^{m}$, Decl. $+8°\ 26'$; R.A. $12^{h}\ 28^{m}$, Decl. $-3°\ 02'$; and R.A. $14^{h}\ 20^{m}$, Decl. $-13°\ 59'$.

The phenomena of the *Moon* will occur as follows:

Full Moon	Sept.	1 at	7 A.M.
Last Quarter		7 "	9 P.M.
New Moon		15 "	12 NOON
First Quarter		23 "	4 P.M.
Full Moon		30 "	3 P.M.
Last Quarter	Oct.	7 "	6 A.M.
New Moon		15 "	4 A.M.
First Quarter		23 "	7 A.M.
Full Moon		29 "	12 MIDNIGHT
Perigee	Sept.	3 "	3 A.M.
"	Oct.	1 "	9 A.M.
"		29 "	9 P.M.
Apogee	Sept.	18 "	7 P.M.
"	Oct.	16 "	2 A.M.

Mercury will be moving back and forth in the constellation of Virgo. Its apparent motion will be direct until September 18 and then again after October 9. During the first part of September it will be in a position favorable for evening observation setting about an hour and a half after the sun. Greatest elongation east will occur on September 4 (27° 05'). Inferior conjunction will occur on September 30 and, after that date, Mercury will be in the morning sky. Greatest elongation west will occur on October 16 (18° 10'). Thus, during the middle of October, Mercury will rise somewhat more than an hour before the sun. On September 15 at 6 P.M. a conjunction with Venus will occur (Mercury 5°.0 N.). Conjunction with the moon will occur on September 17 and on October 13. The distance from the earth to Mercury will be about 98 million miles at the beginning of September. This distance will decrease to about 60 million miles toward the end of September, and will then increase to about 120 million miles by the end of October. The corresponding change in apparent diameter will be from about seven up to ten and back to five seconds of arc. The position of Mercury on the first day of September and the last day of October will be, respectively: R.A. $12^{h}\ 16^{m}$, Decl. $-3°\ 43'$; and R.A. $13^{h}\ 39^{m}$, Decl. $-8°\ 30'$.

Venus will be an evening object setting somewhat more than an hour after the sun. Its apparent motion will be easterly from western Virgo, across Libra and northern Scorpio, to southwestern Ophiuchus. The distance from Venus to the earth will decrease from about 150 to about 125 million miles, and its apparent diameter will increase from about 10.4 to about 12.5 seconds of arc. A con-

junction with Mercury will occur on September 15, and conjunction with the moon will occur on September 17 and on October 17 (Venus 5°.9 N. and 2°.2 N., respectively).

Mars will be a morning object in Leo and its apparent motion will be easterly. During the middle of this period it will rise somewhat more than two hours before the sun. Its distance from the earth will be somewhat more than 200 million miles, and its apparent diameter will be about four seconds of arc. A conjunction with Neptune will occur on October 25 at 10 A.M. (Mars 24′ N.). Conjunction with the moon, will occur on September 13 at 3 A.M. and on October 11 at 9 P.M. (Mars 5°.5 and 6°.7 N., respectively).

Jupiter will be an evening object in southern Ophiuchus. Its apparent motion among the stars will be easterly. During the middle of September it will be toward the south (on the meridian) at sunset. Quadrature east of the sun will occur on September 8. The distance from the earth will increase from about 470 to about 550 million miles. The corresponding change in apparent diameter will be from about 36 seconds of arc to about 31 seconds of arc. Conjunction with the moon will occur on September 22 at 2 P.M. and on October 20 at 5 A.M. (Jupiter 1°.3 and 36′ North, respectively).

Saturn will be a night object in eastern Aquarius. Opposition with respect to the sun will occur on September 11. Thus it will be above the horizon most of the night hours, and its apparent motion among the stars will be retrograde. Its distance from the earth will be about 820 million miles and its apparent diameter will be about 17 seconds of arc. Conjunction with the moon will occur September 2 at 5 A.M., on September 29 at 1 P.M., and on October 26 at 9 P.M. (Saturn 7°.9 S.).

Uranus will be a night object in southern Aries. Like Saturn it will be above the horizon most of the night hours, but it will rise about three hours later. Its apparent motion among the stars also will be retrograde. Opposition with respect to the sun will occur on October 30. The distance from the earth to Uranus will be about 1760 million miles, and its apparent diameter will be about 3.6 seconds of arc. Conjunction with the moon will occur on September 5 at 11 A.M., on October 2 at 6 P.M., and on October 30 at 4 A.M. (Uranus 4°.5 S.). The position of Uranus on October 1 will be R.A. $11^h\ 15^m$, Decl. $+13°\ 58'$.

Neptune will be a morning object in southeastern Leo, but it will be too near the sun in apparent position to be of interest. At the beginning of September it will be about eight degrees from the sun, but, by the end of October, it will rise about three hours before the sun. A conjunction with Mars will occur on October 25 at 10 A.M. (Neptune 24′ S.). The October conjunction with the moon will occur on the twelfth at 1 P.M. (Neptune 6°.5 N.). The position of Neptune on October 1 will be: R.A. $11^h\ 15^m$, Decl. $+50°\ 56'$.

OCCULTATION PREDICTIONS

(Taken from the *American Ephemeris.*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the

Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′.

Date 1936		Star	Mag.	IMMERSION Greenwich C.T. h m	IMMERSION a m	IMMERSION b m	IMMERSION Angle E from N °	EMERSION Greenwich C.T. h m	EMERSION a m	EMERSION b m	EMERSION Angle E from N °
Sept.	5	20 H¹Ari	6.4	7 11.8	−0.6	+3.2	17	8 3.4	−2.4	−1.2	291
	6	ζ Ari	5.0	9 46.7	−1.8	+0.2	78	11 4.7	−1.6	−0.3	256
	9	3 Gem	5.8	6 14.8	—	—	22	6 39.2	—	—	334
	9	6 Gem	6.3	7 5.2	−0.5	+1.6	84	8 11.9	−1.0	+1.0	275
	21	19 Sco	4.8	22 17.0	−1.9	−0.2	73	23 39.4	−1.8	−1.6	291
	24	1 Sgr	5.1	0 50.1	−0.6	+0.9	27	1 41.9	−2.1	−2.5	305
	27	95 B.Cap	6.0	2 52.7	—	—	140	3 5.4	—	—	160
	29	16 Psc	5.6	23 34.3	−0.4	+2.2	32	0 28.8	−1.1	+1.1	271
	30	19 Psc	5.3	5 24.0	−1.4	+0.3	62	6 34.1	−1.1	+0.2	235
Oct.	1	136 B.Psc	6.5	4 28.0	−0.6	+2.5	17	5 22.8	−2.2	−0.8	280
	2	27 Ari	6.4	23 25.7	+0.3	+0.9	102	0 7.1	+0.4	+1.8	219
	4	133 B.Tau	5.9	6 47.9	−1.6	+1.5	62	8 3.1	−1.9	−0.2	272
	4	32 Tau	5.8	10 32.0	−1.4	−0.1	66	11 36.2	−0.8	−1.9	288
	5	τ Tau	4.3	1 51.4	+0.3	+1.2	86	2 43.5	+0.1	+1.4	254
	8	*g* Gem	5.0	5 4.6	+0.1	+0.2	91	6 3.1	−0.3	+0.8	285
	21	28 Sgr	5.8	23 3.1	−1.1	+0.4	42	0 13.0	−1.8	−1.6	281
	31	τ Ari	5.2	7 13.0	−1.6	+1.2	46	8 12.1	−1.3	−2.1	294

OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′.

Sept.	2	κ Psc	4.9	11 9.7	−1.0	−4.3	130	11 34.6	0.0	+3.6	178
	6	ζ Ari	5.0	9 11.6	−1.7	+1.2	70	10 31.5	−1.9	+0.6	254
	9	6 Gem	6.3	6 59.1	+0.2	+1.7	70	7 55.1	−0.5	+0.8	286
	25	199 B.Sgr	6.4	3 44.2	−1.7	−1.5	104	4 42.2	−0.1	+0.5	213
	27	95 B.Cap	6.0	1 57.9	−2.4	+0.1	98	3 1.8	−0.9	+1.6	203
	29	16 Psc	5.6	23 25.6	0.0	+2.2	27	0 10.2	−0.5	+1.0	282
	30	19 Psc	5.3	4 56.1	−1.2	+1.6	41	6 7.8	−1.7	+0.3	251
Oct.	4	133 B.Tau	5.9	6 21.5	−0.8	+2.3	47	7 26.9	−1.8	+0.2	280
	4	32 Tau	5.8	10 1.0	−1.9	+0.1	79	11 18.5	−1.6	−0.8	268
	7	ζ Gem	3.7	12 41.7	—	—	178	13 10.5	—	—	218
	18	27 G.Sco	5.8	23 33.2	−1.2	−1.1	86	0 47.6	−0.7	−1.4	272
	21	28 Sgr	5.8	22 35.3	−1.5	+1.9	26	23 34.3	−2.9	−1.7	305
	22	30 Sgr	6.2	1 23.1	−0.9	0.0	52	2 33.1	−1.1	−1.3	268
	25	72 B.Aqr	6.5	0 40.8	—	—	116	1 23.4	—	—	181
	31	τ Ari	5.2	6 39.7	−1.6	+1.8	47	7 42.2	−2.0	−1.1	284

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′.

Sept.	2	κ Psc	4.9	10 28.8	−2.3	−1.5	104	11 18.6	−0.4	+2.4	191
	6	ζ Ari	5.0	8 34.7	−0.3	+2.5	38	9 33.9	−1.6	+0.6	279
	6	τ Ari	5.2	12 14.9	—	—	151	12 34.7	—	—	177
	9	η Gem	3.3	8 13.0	−0.7	−1.2	151	8 37.8	+1.2	+3.4	206
	9	μ Gem	3.2	11 58.2	—	—	159	12 29.2	—	—	205
	10	56 Gem	5.2	12 53.4	−1.4	+1.6	80	14 8.7	−1.9	−0.8	303
	21	169 B.Lib	5.8	3 20.8	−2.1	−3.6	151	3 59.2	+0.3	+1.1	214
	25	199 B.Sgr	6.4	2 47.3	−2.2	+0.5	72	4 15.3	−1.9	0.0	248
	27	95 B.Cap	6.0	1 2.2	−1.3	+1.4	84	2 14.3	−1.5	+1.7	232
	30	19 Psc	5.3	4 28.9	—	—	354	5 0.2	—	—	302
Oct.	4	133 B.Tau	5.9	6 11.6	—	—	4	6 33.5	—	—	322
	4	32 Tau	5.8	9 4.2	−1.5	+1.5	70	10 22.4	−2.0	+0.7	260
	21	4 Sgr	4.8	2 5.2	−1.5	−0.3	71	3 25.1	−1.2	−0.9	260
	22	30 Sgr	6.2	0 43.8	—	—	20	1 38.4	—	—	308
	23	57 Sgr	6.0	5 53.1	—	—	138	6 13.5	—	—	174
	24	72 B.Aqr	6.5	23 39.3	−1.3	+1.2	92	0 45.4	−1.3	+2.1	218
	31	τ Ari	5.2	6 1.8	0.0	+3.6	17	6 44.5	−2.5	−1.0	303
	31	63 Ari	5.2	6 40.8	—	—	148	6 56.7	—	—	173

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

As there are no specially interesting reports from our members now at hand, and as the writer has no review of work done elsewhere that is suitable for publication here, this opportunity is taken to give the solutions for three fireballs. As usual, the derived data differ widely in accuracy, but attempts have been made to call attention to their probable precision. We have ready for publication solutions on a number of other fireballs. They will appear in these notes from time to time.

All A.M.S. members are again urged not to neglect the opportunities offered by the meteor showers in the summer months, and to remember that all through the late summer and fall meteors are more numerous than in the first half of the year.

The Michigan Daylight Fireball of 1934 February 9

At 4:50 P.M., E.S.T., on 1934 February 9, just before sunset, a fine fireball coming from south of west crossed Michigan and ended over Gratiot County. One of our Michigan members, B. C. Darling of Lansing, at once made great efforts to secure as many observations as possible, both through the local press and by personal letters. A few observations came directly to the American Meteor Society, which also made an appeal through certain Michigan papers. By these means, principally through the excellent work of B. C. Darling, 48 observations from 30 stations were reported to headquarters.

As the meteor appeared in the daytime, there were no stars for reference points; and as it left no long-enduring train which might have been measured more or less at leisure, that method of fixing its path was also unavailable. Nearly all of the estimates were therefore merely "dead-reckonings" made from memory, and many of them were made some days after the event. It is believed further that this was the first such report submitted by all but one or two of the observers. No high degree of accuracy can be expected in the results under such disadvantageous conditions.

A study of the reports showed that few of the observers saw the first part of the path at all; the majority, in fact, saw only the last third of it. This was largely because the fireball came almost from the direction of the setting sun as seen from most stations. The sub-end point, however, can be fixed reasonably accurately, and the plane of motion is probably correct within 2 or 3 degrees. The rest of the data, even the end height, cannot be held as well-determined. The usual table of data follows:

Sidereal time at end point	22° 14′
Began over $\lambda = ?$, $\phi = ?$	probably over Lake Michigan
Ended over	$\lambda = 84°\ 34'$ W, $\phi = +43°\ 26'$
Beginning Height	Indeterminate
End Height	42 km
Length of Path	>202 km
Projected Length of Path	>197 km
Observed Slope of Path	12° ±
Azimuth of Motion (towards)	254°
Observed Velocity	Slow; indeterminate
Radiant	R.A. = 114°, Decl. = +20°

While there was the usual diversity in color estimates, most persons called the fireball white or yellow; the short-lived following train of sparks and smoke (?) probably was of a bluish tint. Everyone stated positively that there was but one object except for "sparks" or very small fragments left as the main body went along. So many stated that the path was horizontal that the angle with the horizontal plane was evidently small. Making allowance for projections, 12° seems about right; this could hardly be wrong by more than 6° at most. The azimuth is principally determined by the station at Muskegon Heights, which reported that it went through the zenith, and by stations at Grand Rapids and Fremont, which reported that it went relatively near their zeniths but on opposite sides. It is a great pity that observations near the actual end point are wholly missing, and that we have none from beyond this point to north or east. We do not know whether this was due to a dearth of observers, to local clouds, or to lack of publicity. While it is most regrettable that not all of the usual data could be deduced, there can be no object in including those which are so uncertain as to be useless. We cannot be sure whether any meteorites fell. Mr. J. K. Jacobs has a stone picked up 5½ miles northeast of Sheppard, on a farm adjacent to his own, which he has some idea is meteoric, but he declines to let it out of his possession for analysis. Besides this, no report of a possible meteorite is known.

The greatest credit for this report goes to B. C. Darling of Lansing, Michigan, an A.M.S. member, who collected most of the data. Acknowledgments are also due to numerous Michigan papers which kindly printed requests for observations, and of course to each person who was good enough to send in a report.

From Frank Preucil, Joliet, Illinois, a member of the American Meteor Society, we have the following (abstracted) observation: at about 3:00 P.M. (C.S.T.?) on February 9, while driving near $\lambda = 88° 07'$, $\phi = 41° 28'$, he saw a fireball, about one-fourth the diameter of the moon and pale green in color, falling vertically in azimuth 228½°, from $h = 32°$ to $h = 25½°$. Although the 50± minutes of time difference makes it impossible for this to be the same object seen by the others, the plane of motion was nearly parallel and the two objects may have been physically connected.

New Jersey-Pennsylvania Fireball of 1934 October 17

At $9^d\ 26^m\ 20^s \pm 10^s$, E.S.T., on the evening of October 17, 1934, a brilliant fireball began over central New Jersey, traveled in a general northwest direction, and ended over northeastern Pennsylvania. As it was promptly reported, newspaper notices could be sent out at once, and in due time a large number of observations were received. To some observers questionnaires or follow-up letters were then mailed. Altogether about 150 persons reported; some use could be made of about 37 of these reports for the numerical conclusions given in this paper.

Fortunately, Dr. J. Q. Stewart was on the roof of Princeton Observatory with several students. The observations made there were given special weight. Several other observers (H. A. Rand at Holicong, Pa., N. Lachno at Bangor, Pa., C. Griffith at Drexel Hill, Pa., and W. R. Cook at Collingswood, N. J.) sent in plots of the fireball's path among the stars, and a few others made useful drawings from which angles could be estimated. The rest made "dead-reckoning" observations.

Though considerable time was spent on the computations, even the better observers could not be made to agree on the beginning height; the unweighted mean of twelve observations was finally used. The end height was far better determined,

though for the final value only those who used some method other than dead-reckoning were included—ten in all. There seems no doubt that the path actually curved considerably: J. F. Rau, at Philadelphia, said that the angle was 80° (to vertical?) at start, 50° at end. Others sent in sketches indicating a curved path. The Princeton observers, being in the actual plane of motion or almost so, did not observe any curvature. In any case, the observations are too discordant to permit an accurate attempt at allowing for curvature. If this could be done properly, the altitude of the radiant as given undoubtedly would be higher.

The usual data follow:

Began over	$\lambda = 74° 46'$ W, $\phi = +40° 29'$
Ended over	$\lambda = 75° 26'$ W, $\phi = +41° 14'$
Ground point	$\lambda = 75° 42'$ W, $\phi = +41° 33'$
Local Sidereal Time at Ground Point	347°
Beginning Height	185 km ± 66 km (12 obs.)
End Height	52 km ± 15 km (10 obs.)
Length of Path	205 km
Projected Length of Path	151 km
Duration	4^s.15 ± 1^s.57 (17 obs.)
Apparent Velocity	49 km/sec
Radiant (uncorrected)	h = 41° ; a = 326°

For once, strangely enough considering the other probable errors, the time of flight and azimuth of the plane of motion seem fairly well determined. Also there is good agreement that the head of the fireball was probably about one-quarter of the moon's angular diameter as seen by distant observers, and larger for those nearer. It had a brightness greater than the moon, according to some, and was blue in color, while the sparks left behind were reddish. The sparks or other parts of a most conspicuous "train" (many degrees long) lasted only about 3 seconds. Definite sound phenomena were reported by J. Ward, at Bangor, Pa., who said: "Immediately following the meteor was a huge gas ring of blue and purple coloring and after the disappearance of the meteor and gas ring a loud rumble like thunder was heard. The gas caused by the meteor completely obliterated the moon which was shining very brightly at the time." He adds that it was three minutes after the meteor was seen that the sound was heard.

N. Lachno, also of Bangor, did not himself hear the sound but had reports from two men, one of whom said he heard "a thunderous roll" five minutes after the meteor, the other of whom reported that the sound was heard two minutes after. N. J. Heines of the A.M.S. reported that "S. J. Ackerson at Cozy Lake tells me that the explosion shook his windows and actually rattled his back door. This statement has been told me by several others in the immediate vicinity and at Stockholm the explosion was not so severe as at Cozy Lake. It seemed to center there." Men near the monument at High Point Park, N. J., heard "a slight detonation."

There seems to have been more than one flare-up in brightness, and it is certain that the object disappeared well above the horizon for nearly all observers. The end height seems rather large for debris of any size to have fallen as meteorites. Many report that a very definite explosion was seen.

We are greatly indebted to the numerous people and newspapers who aided in collecting or reporting observations. Lack of space prevents our printing the very long list of their names.

Daylight Fireball of 1935 October 22

At 5:12 P.M., E.S.T., on October 22, 1935, while it was daylight, a brilliant meteor started over a point a little south of Albany, N. Y., and moving in a S.E.

direction ended nearly over West Hartland, Conn. As the press carried requests for observations, many were sent in, and also several persons were interviewed personally. Later, more observations reported to Harvard College Observatory, Columbia University Observatory, and Yale Observatory were kindly turned over to me. Therefore we have about 103 reports on which to base our results. However, as there were no stars to serve as reference points, most people made only "dead-reckonings," which are subject to large errors of judgment. Many simply described the object. A few made measures with sextant, cross-staff, or transit, and thanks to these we are very confident of the end height.

The average estimate of color for the meteor was blue-green and its apparent size from one-quarter to one-half that of the moon. Had it been night when this fireball appeared, it would have been a most brilliant object. Its train was long and bright, lasting however only 3 seconds, which is barely longer than the estimated time of the flight itself. The meteor is described as "an inverted exclamation point" in shape. Many say that it burst at the end of its path; at any rate it ended with a considerable increase in brightness. Nobody heard an explosion, but we have several, as usual, who report that their attention was called to the meteor by a cracking or hissing sound. As pointed out formerly, this "sound" if interpreted in the ordinary sense of the word could not be caused by the meteor, as what is "heard" is coincident with the appearance of an object which for most observers is from 50 to 200 miles away. If it is not psychological, perhaps some sort of electrical effect is responsible for the reported sensations. The matter should not, however, be dismissed as incredible merely because we cannot assign a certain cause for it, as apparently reliable observers have vouched for its reality on many occasions.

The following data have been derived:

Began over	$\lambda = 73^\circ\ 48'$ W, $\Phi = +42^\circ\ 36'$
Ended over	$\lambda = 72^\circ\ 58'$ W, $\Phi = +42^\circ\ 04'$
Ground Point	$\lambda = 72^\circ\ 45'$ W, $\Phi = +41^\circ\ 56'$
Local Sidereal Time at Ground Point	$290^\circ\ 40'$
Beginning Height	$185.6\text{ km} \pm 44.1\text{ km}$
End Height	$35.4\text{ km} \pm 15.1\text{ km}$
Length of Path	175 km
Projected Length of Path	90 km
Observed Geocentric Velocity: highest estimate, 188 km/sec; lowest, 59 km/sec	
Radiant	$h = 59^\circ.2$; $a = 131^\circ$
Zenith correction (max.)	$0^\circ.3$
Radiant corrected	$h = 58^\circ.9$; $a = 131^\circ$
R.A. $= 247^\circ.2$, Decl. $= +55^\circ.5$	Long. $= 214^\circ.4$, Lat. $= +74^\circ.6$

The projected path was found in the usual way for such cases, by plotting the observed azimuths on a large-scale map. A study was then made of the probable reliability of the observations and the weighted center of gravity of the intersecting lines chosen by inspection. Such heterogeneous data do *not* justify the labor of a least-squares solution. Using the distances from the projected beginning and end points, and the observed altitudes corrected for the earth's curvature, heights were computed for each observer. Fortunately we have four observations of end points made with instruments; their mean is 31.6 ± 3.3 km. We have 13 other estimates of the altitude which appear reliable for a variety of reasons. These give 39.1 km. We have finally taken the end point as 35.4 ± 15.1 km, and believe it to be far better determined than the average deviation indicates. The beginning point is necessarily more poorly determined, for each person sees the meteor a different, if small, fraction of a second after its true appearance. This

greatly complicates the computation. The adopted value, 185.6 ± 44.1 km, cannot be considered known within less than 15%. The very best *measured* value of the beginning point, made by Miss Atanasoff at Wellesley College, gives 192.2 km, in good agreement with the adopted value. Any uncertainty in the height of beginning seriously affects the derived length of path, the velocity, and the altitude of the radiant. While we have to emphasize the large possible errors in one height, in justice to the observers let it be said that in most cases their estimates of altitude were apparently correct within 5° or 10°. This is really good for daytime observations and allowing for the fact that everyone was caught wholly unawares and without any instrument at hand. The azimuth of the radiant, which is merely that of the projected path, seems pretty well determined. However, because of the uncertainties mentioned, any orbital elements would be most unreliable. We are able to prove without doubt that the object moved with direct motion, the inclination of the orbit being 42°, assuming parabolic velocity, which is certainly too low. As the estimates of its time of flight combined with the derived path length give from 59 to 118 km/sec as the observed geocentric velocity, and as it overtook the earth, there seems no possible doubt that its heliocentric velocity was strongly hyperbolic and hence that the fireball came from without the solar system. I wish gratefully to acknowledge the receipt of reports forwarded by Harvard College, Columbia, and Yale Observatories (mentioned in the order of number received), and also to express appreciation to numerous persons who took an active part in obtaining further data for this paper, as well as to the scores of observers without whose aid these fireball results would be unobtainable.

Flower Observatory of the University of Pennsylvania,
Upper Darby, Pennsylvania, 1936 July 3.

The Lord Cast Down Great Stones From Heaven

By C. C. WYLIE

In the account of the defeat of the five kings by the armies of Israel under the leadership of Joshua (Joshua 10:11), it is stated that as the defeated armies were fleeing, "the Lord cast down great stones from heaven upon them unto Azekah, and they died: they were more which died with hailstones than they whom the children of Israel slew with the sword." Many writers have assumed that, in spite of the word "hailstones," the account refers to a shower of meteorites. The following are typical quotations from writers who assume that this was probably a shower of meteorites.

Moulton, ASTRONOMY, page 297. "Meteorites have been known from remote antiquity. In the tenth chapter of the Book of Joshua there is a brief account of 'great stones from heaven' which fell upon the enemies of the children of Israel and killed them."

Olivier, METEORS, page 3. "The evidence is overwhelmingly strong that we have here the account of the fall of a number of meteorites rather than hailstones. That the narrator doubtless exaggerated the relative number of men killed by them is wholly immaterial and to be expected under such unheard of circumstances."

Nininger, OUR STONE-PELTED PLANET, page 2 and 3. "The account in Joshua of Jehovah raining stones on the enemies of the Israelites is another illustration of how the Hebrews regarded the fall of meteorites. And doubtless the enemy

upon whom they chanced to fall regarded it with the same degree of superstition. But we are not favored with their account of the episode."

However, not all writers have assumed that this refers to a shower of meteorites. In Maunder, THE ASTRONOMY OF THE BIBLE, page 373, this is interpreted as a hailstorm. Maunder refers to "the hailstorm which fell upon them whilst rushing down the precipitous road between the Beth-horons; a storm so sudden and so violent that more of the Amorites died by the hailstones than had fallen in the contest at Gibeon."

To decide between the two alternative interpretations, let us first examine the narrative in the original rather than in the translation. Here there appears to be no ambiguity. The Hebrew word which is translated "hail" is the same as that used in the ninth chapter of Exodus where there can be no doubt that a hailstorm is referred to. The intent of the author was, therefore, to describe a hailstorm, not a shower of meteorites.

A study of historical accounts of the fall of meteorites has led the writer (*Contributions of the University of Iowa Observatory,* Number 2, page 59, Number 5, page 163) and others to the conclusion that in all history there is no definitely authentic account of the injury of man or animal by a meteorite. For some falls, hundreds of meteorites have fallen in a thickly settled community without even striking a house. There is probably only one recorded fall where an army in full flight would have been in serious danger of losing more than one or two men, even had the men been grouped where the meteorites were falling the most thickly. This single exception is the fall in Siberia in 1908 for which the information at present is quite meager. We are told that a considerable number of reindeer were killed. However, the Siberian fall would have been referred to as fire from heaven. The damage was caused by the explosion of the great meteor when striking. We cannot imagine anyone describing such a meteor as "great stones from heaven," so it appears highly improbable that this account can refer to a fall of meteorites.

On the other hand, hailstorms of sufficient severity to kill both men and animals are of relatively frequent occurrence. Mr. Charles D. Reed, Senior Meteorologist of the United States Weather Bureau in Des Moines, Iowa, writes that "In Iowa, almost every year, we have a report somewhere of disk-shaped hailstones approximately six inches in diameter with a thickness in the middle of two to two and one-half inches and at the edge of about one inch, which strike the roofs of houses with such force that they go through shingles, sheeting and plaster into the upstairs rooms. Occasionally we have reports of horses being killed and more frequently of calves, pigs, and sheep being killed. I cannot recall a case of a person being killed by hail in Iowa though I would credit such a report in view of the tremendous force of one of these six-inch hailstones."

The largest hailstones recorded in the Middle West in recent years fell in Nebraska. The circumference of one globular stone was seventeen inches, making the diameter almost five and one-half inches. This is larger than a good sized grapefruit. The fact that no deaths of human beings from hail have been recorded in the State of Iowa is doubtless because men always seek cover at the approach of such a storm. There are, however, occasional records of persons being knocked unconscious by hailstones before reaching cover. For example, on May 17, 1936, a severe hailstorm struck Omaha and Council Bluffs. At Omaha, Nebraska, the hail accompanied by heavy rain was washed and blown into drifts two or three feet deep in places. At Council Bluffs, Iowa, across the river from Omaha, Mr. Theodore Matson was knocked unconscious when struck by a large

hailstone. The greatest number of deaths from a single hailstorm in modern times is probably that from a hailstorm which occurred about one hundred miles east of Delhi, India, on April 30, 1888. More than two hundred and fifty persons perished in this storm. A few were killed by falling trees, but the vast majority of those killed were persons caught in the open and without shelter who were simply pounded to death by the hail. The storms in tropical India are probably more severe than those in Iowa, and many of the poorer people live in flimsy dwellings which are of little value as protection from hailstones which may be larger in size than an ordinary grapefruit. A considerable number of these persons were probably killed outright by the large hailstones. The meteorologist who

DRIFTED HAIL AT OMAHA, NEBRASKA, MAY 17, 1936.
(Photograph by *The Omaha World-Herald*)

investigated the storm believed that many who perished were at first merely knocked unconscious. As they lay in this condition their bodies were packed in ice, and they perished from exposure. The accompanying picture, made in Omaha on May 17, 1936, shows hail covering the running board of a car. Unconscious persons would surely perish if buried in such drifts.

In the spring of 1932 a letter was dispatched to India making inquiry on the report of two hundred and fifty deaths from the storm of 1888. In reply we were told that this information was from a paper published in an official journal by a meteorological observer in India. A newspaper clipping was enclosed which reported on a storm in Allahabad, on May 5, 1932. "Thirteen human beings, as far as is known, lost their lives, chiefly from the hail. The majority of these were old men and women and children. A number of others received minor injuries.

Over one hundred cattle were reported to have been killed." Evidently in some tropical and subtropical climates, hailstorms of sufficient severity to kill persons caught without shelter are not uncommon.

The defeated army referred to in the Book of Joshua was in full flight down a rocky valley and with little or no chance for cover. A hailstorm dropping stones three or more inches in diameter would no doubt have killed a considerable number of the men.

In conclusion, three lines of evidence lead us to believe that the reference in Joshua is to a fall of hailstones rather than a fall of meteorites. First, the Hebrew word used in the narrative unquestionably means hailstone. The intent of the author was, therefore, to record a hailstorm. Second, an investigation of accounts of meteoric falls has failed to reveal an authentic record of injury to either man or animal by falling meteoric stones. (The hot gases from the explosion caused the damage in Siberia.) Third, an investigation of records of hailstorms reveals that storms of sufficient severity to kill both men and animals caught without protection are of relatively frequent occurrence. In modern times there is a record whose authenticity is not disputed of a single storm killing more than two hundred and fifty persons. It appears, therefore, that the translators were correct in using the word "hailstones" in this passage.

University of Iowa, Iowa City, Iowa, July 10, 1936.

Contributions from the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD, President, *and* H. H. NININGER, Secretary

The Tektite Problem*

By L. J. SPENCER,
Keeper of Minerals, British Museum of Natural History, London, England

The natural glasses, found as small corroded pieces scattered on the earth's surface and in alluvial deposits in a few limited areas, have long presented a puzzling problem; and many theories have been propounded to explain their origin. They have been known in southern Bohemia and western Moravia since before 1787; and similar material has since been found in the Dutch East Indies, Malay States, Australia, Tasmania, French Indo-China, south China, Philippine Islands, and quite recently in the Ivory Coast in West Africa. These glasses are distinct in chemical composition from volcanic glass (obsidian), and there are no volcanoes in the districts where they are found. They have been given the names *moldavites, billitonites, australites, Darwin glass, indochinites, rizalites, etc.*

In 1900, Professor F. E. Suess of Vienna included all these under the term *tektites,* and he put forward the theory that they are of meteoritic origin. This theory has found general acceptance, but as a matter of fact there is no direct evidence for its support. None of these glasses has been seen to fall from the sky; and they are quite different in chemical composition and structure from any meteorite (siderite or stone) actually observed to fall. Differing from all known terrestrial materials (except those quite recently recognized around meteorite craters) and being found under strange circumstances, it is perhaps natural to

*An invited paper read at the Fourth Annual Meeting of the Society, University of California at Los Angeles, June 23 and 24, 1936.

assume that they have simply fallen from the sky. Professor Suess's main argument that they are of cosmic origin was based on a certain similarity in the surface sculpturing to that seen on meteoritic stones; and he assumed that this was produced by friction and corrosion in the earth's atmosphere. But similar surfaces are shown by weathered rocks (especially limestone), and it is now generally admitted that the peculiar types of sculpturing shown by tektites are due to chemical corrosion by humic acids in the soil.

The peculiar forms of australites ("black fellows' buttons") cannot, however, be explained in this way. These were produced no doubt by the spinning of a viscous mass. It has therefore been assumed that the glass was melted by the heat developed by friction in the earth's atmosphere. It is well known that the surface of meteorites is fused during their rapid passage through the atmosphere. But it is evident that this fused material must be wiped off (ablated) as quickly as it is formed, so producing the fiery trail of fireballs. When meteorites reach the ground they are seen to be covered with a thin skin of glassy material (the fused crust), which rarely exceeds a millimeter in thickness. It is evident that meteorites that reach the ground are only a fraction of their size when they entered the earth's atmosphere; and it is only really big ones that have a chance of getting through. A blob of molten material traveling at a high velocity would not hold together. Rain does not come down in lumps.

The suggestion was made by H. Michel in 1925, and more recently supported by A. Lacroix and F. E. Suess, that tektites have been formed in a molten condition in the earth's atmosphere by the burning of meteoritic masses of the element silicon (Si) with some metallic aluminium, calcium, potassium, *etc.* But such a burning would surely cause the dispersal of the matter in a fiery trail.

Further, as recently pointed out by Fletcher Watson, Jr., in a letter to *Nature* (London, 1935, **136**, p. 105), time is required for the conduction of heat into a solid body. Even with the higher degree of conductivity of siderites, the heating zone, shown by the transformation of α-iron to γ-iron (which takes place at a temperature of 850° C.), extends to a depth of only a few millimeters. This fact indicates that the molten material is wiped off of the surface in the rush of air as quickly as heat is conducted into the interior of the mass. Meteoritic stones also show only a very slight heating effect beyond the fused glassy crust.

It is thus clearly impossible that tektites could have been completely fused during a very brief flight through the earth's atmosphere. Dr. Charles Fenner has recently (1935) suggested that the peculiar button shape of australites has been formed by ablation from a sphere of solid glass entering the atmosphere.

Tektites contain from 70% to 80% of silica and are an impure form of silica-glass. In recent years the presence of silica-glass in large quantities has been recognized around the undoubted meteorite craters at Canyon Diablo in Arizona, Wabar in Arabia, and Henbury in Central Australia. It has here been formed by the melting of sandstone or desert sand in the intense heat generated by the impact of a really large mass of meteoritic iron. The air resistance is proportional to the square of the radius of the body, while the momentum is proportional to the cube of the radius. Hence a large mass will reach the earth's surface with a greater velocity. The kinetic energy, measured by $\frac{1}{2}mv^2$, will be suddenly transformed into heat, giving rise to a violent gaseous explosion and the formation of a crater. The material from Wabar affords ample evidence of extremely high temperatures. The molten silica not only boiled, but was vaporized; and the meteoritic iron also was vaporized and came down again as a fine rain.

The Darwin glass from Tasmania, which has been classed with the tektites,

compares exactly in its form and chemical composition with the silica-glass from Wabar. It occurs over a wide area in glacial deposits, but no trace of meteoritic iron or of meteorite craters has been found there. However, the iron would soon be destroyed by weathering, and the craters obliterated by glacial action and denudation. The silica-glass is very resistant to chemical action, and also, on account of its very low coefficient of thermal expansion, it is not broken by changes of temperature. It therefore has remained to tell the tale.

This meteorite-crater theory of the origin of tektites, which I first advanced in 1933 (*Nature*, London, **131**, p. 117; *Comp. Rend. Acad. Sci. Paris*, **196**, p. 710), has been criticized on the ground that tektites are found over a much wider area than that occupied by meteorite craters, and that they are not always found in the neighborhood of the right kind of rocks to yield such a fused product. The local distribution of tektites must, however, be considered in connection with not only recent but also ancient systems of drainage, and perhaps also (as in Tasmania) with glacial action. And further it must be remembered that silica-glass is a material that will survive for a long period. But I must admit that the peculiar forms and the very wide distribution of australites present a difficulty. Still we have for this theory some scraps of positive evidence, whereas the meteoritic theory is based only on negative evidence.

Closely allied to tektites, and no doubt to be classed with them, are the lumps (of weights up to 16 pounds) of almost pure silica-glass (SiO_2, 97½%) recently found in the Sand Sea of the Libyan Desert. This material is clear, with a yellowish-green color, and is suitable for cutting as gemstones. It presented such a strange problem that I was glad to have the privilege of joining a special expedition of the Survey of Egypt to investigate the matter in December, 1934. The glass was found sparingly scattered over an area of 85 by 35 miles with the largest amount at our Camp 7, lat. 25° 17′ 54″ N., long. 25° 34′ 0″ E. Unfortunately we were not able to trace the material to any source, and no trace of meteorites or of meteorite craters could be found amongst the high sand-dunes. It seemed easier to assume that it had simply fallen from the sky! But the problem still remains unsolved.

Why is a Meteor?*

By H. H. Nininger

Today there came a letter from a student of astronomy in the State university of an adjoining State, describing a great fireball which he had seen at high noon the previous day. "My teacher said you would be interested in this report." I read the letter carefully: "traveling just above the mountains . . . trajectory forming a 9° angle with the horizon . . . first seen at an elevation of 18°, vanished at 9° as measured on a theodolite . . . slightly above the crest of the mountains . . . looked one-fourth as large as the full moon," *etc.* The story was accompanied by well executed drawings. His instructor was right. I was interested; intensely interested. I shall always be interested in such momentous events, as long as my mind is capable of taking an interest in anything. Only two weeks ago a man in another neighboring State had reported seeing a daylight meteor. This man had previously accompanied me on some of my "meteor-chasing expeditions" and knew what information was desired. Notices were sent

*Read at the Fourth Annual Meeting. In this paper the term *meteor* is used to denote the light phenomena occasioned by the plunge of a meteorite through the atmosphere.

out and it was soon learned that the meteor had been about 350 miles from the observer when he saw it!

Again and again in the past dozen years, I have encountered witnesses of daylight falls who have viewed these spectacles from distances of 200 to 300 miles. No other terrestrial phenomena are viewed from such great distances. It is true of course that no other phenomena occur in so auspicious a location for distant vision; yet it is true also that there are very few terrestrial phenomena which would be large enough to be seen from such distances even if they took place in the stratosphere as do meteors. Extensive cloud masses, general storm conditions, and occasionally a volcanic outburst of unusual magnitude, may surpass in extent the great meteoric displays, but among all other mundane events, meteors stand supreme. A few years ago I stood within half a mile and witnessed the discharge of 202 tons of explosives in a single blast. I do not now recall the estimated tonnage of rock displaced by that great explosion as the crest of a mountain crumbled and fell away, but I am certain that even the great cloud of dust which arose would not have been visible a hundred miles away, and the moving mass of rock would not have appeared important from a distance of even 20 miles. As for the other aspects of the occurrence, the detonation, the earth tremors, and the house-shakings, these impressed me no more from where I stood than our great meteors have impressed those who have witnessed them from distances of 20 to 50 miles, according to the mental pictures which I have formed out of thousands of interviews with eyewitnesses of these events. The intensity of detonations and quakes produced by explosions varies inversely as the square of the distance from the point of origin. Thus, when a meteor heard from a distance of 50 miles is compared to thunder arising from lightning at a distance of half a mile, we may fairly assume that the meteor's disturbance was approximately $(2 \times 50)^2$ or 10,000 times as forceful as was that of the lightning! If this statement seems at first thought to be an exaggeration, it is only because we are not accustomed to dealing with the phenomena accompanying meteorite falls. To any one experienced in meteor surveys, these statements must seem very realistic.

The accompanying illustration (Fig. 1) represents a phenomenal volcanic outburst, that of Kilauea in 1924. Such an eruption, though not especially uncommon when considering the earth's surface as a whole, is yet so spectacular and of such violence, that it engages the attention not only of the general public but also of the scientific world. Yet it is doubtful whether such a disturbance would receive more than passing notice were it taking place 50 miles up in the stratosphere, and lasting only a few seconds. The cloud here shown had a volume of only about one cubic mile. It was of course photographed from a point comparatively near by. The other photograph, reproduced in Figure 2, shows the cloud left by the famous meteor of March 24, 1933. This cloud floated at an elevation of 30 to 50 miles and its nearest point to the photographer was 240 miles away. The portion shown farthest to the right in the picture represents the most distant part of the cloud, which was 200 miles long and was photographed almost end-on. As viewed from man's terrestrial abode the volcanic cloud was far more impressive; but if it had been seen from an equal distance, this eruption would have appeared too insignificant to be compared with the great meteor cloud which filled a volume of a thousand cubic miles thirty minutes after its formation! Figure 3 shows in flight the meteor which produced this cloud. The great luminous sphere which forms the center of the picture was six miles in diameter, while the column stretching behind it was a mile in width. Actual measurements made on the photograph (Fig. 3) prove beyond a doubt that this column was larger in diameter

as it issued from the flying meteor than was the impressive outburst seen rising from Kilauea in Figure 1.

The meteor under discussion was an impressive sight from distances of 350 to 400 miles. Those persons who were as near as 50 and 75 miles experienced a very considerable earthquake and witnessed a sight never to be forgotten. Seasoned cattlemen who were accustomed to facing the vicissitudes of frontier life

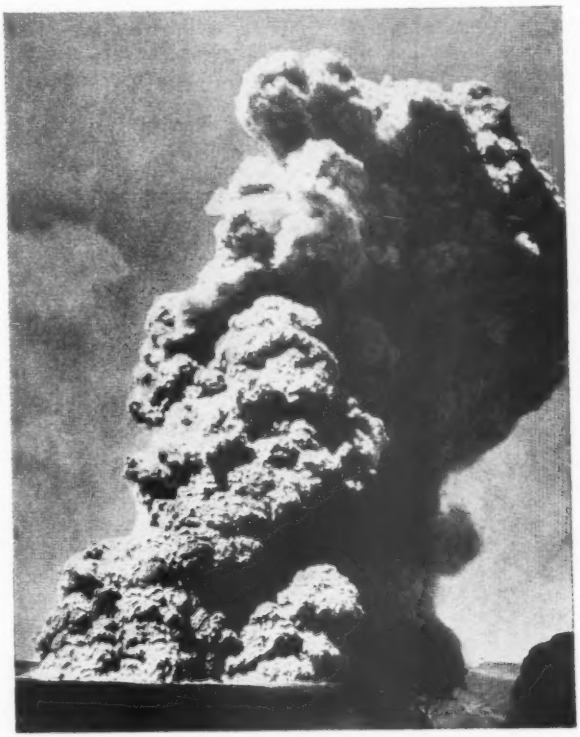


FIGURE 1

A volcanic cloud arising from Kilauea in 1924. This cloud filled a volume of about one cubic mile.

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and who ordinarily knew no fear, told me that they despaired of life during the terrible moment of the meteor's passage; yet they were 75 miles from its nearest approach! Such phenomena would be unendurable if viewed from distances such as those from which ordinary volcanic activity is commonly observed. Each year events of the kind just described occur somewhere on our planet; however, the scientific world knows as yet but little concerning them. Many scientists accept

uncritically the view of the man of the street that the phenomenon was "just another shooting star."

What really happens when a meteorite plunges into the atmosphere and leaves in its wake a dense cloud 2,000 to 5,000 feet in diameter and from 30 to 200 miles long? Recent discoveries in the field of aërodynamics throw some light on this question. Until recently physicists assumed that for bodies moving through the atmosphere, the relation between velocity and friction remains constant; namely, that friction increases as the square of the velocity. Recently it has been learned that this rule holds with only those velocities which are relatively very low, such as the speeds of motor vehicles. The startling discovery has been made that at about the speed of sound there is a sudden, enormous change in the ratio, which is expressed as the velocity raised to the sixth power! This result means that doubling the velocity of a body multiplies the resistance which it encounters by 64. This fact has tremendous implications, for remember that the velocity of

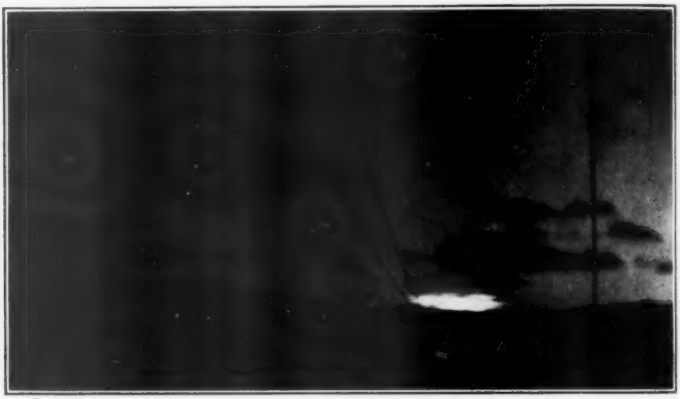


FIGURE 2

The luminous meteor cloud as it appeared about 5:30 A.M., March 24, 1933, from Albuquerque, New Mexico. Distance from photographer: about 240 miles. Lens: 6½-inch focus. Photographer: H. A. Brooks.

sound is almost no velocity at all in comparison with the speeds at which meteorites enter the atmosphere. If doubling the speed of an ordinary projectile means that it must overcome 64 times its former resistance handicap, what, we may inquire, would be the resistance encountered by a body moving one hundred times as fast? The engineers have not been able to answer this question. They find themselves limited in their experiments to an extremely small number of bodies that move at the relatively leisurely speed even of sound; bullets and the tips of aëroplane propellers are about all they have to experiment with! If we could only devise a means of scrutinizing the surface of a mass of iron which pierces our aërial blanket at the devastating velocity of 8 to 44 miles per second,[1] we should be able to conjecture as to how many thousands of times the greatest

[1] Recent investigations indicate ever higher velocities than 44 mi/sec in the case of some meteorites.

known aërial resistance is multiplied in the case of an invading meteorite. At present only one avenue is open to us for the gaining of knowledge concerning this unparalleled case of frictional resistance. We can examine its effect only after that effect has been recorded on the surfaces of fallen meteorites. Here we may see how enormous masses of iron have been, within a few seconds, shaped as though by a giant turning-lathe. We see where flinty, hard, and ultra-brittle olivine has been wiped off as deftly as though it were a bit of sea foam. We see where a dozen brittle minerals of different melting points embedded with nodules of tough nickel-steel have all been wiped off together as though they were of one

FIGURE 3

The photograph taken by Mr. Charles M. Brown of the meteor of March 24, 1933, while it was in flight. The kodak faced an altitude of about 40° as the meteor approached the zenith.

and the same material. We see where large ragged fractures have been seared over within a fraction of a second. All these manifestations we see in specimens where only that work of friction is recorded, which has been accomplished during the last feeble stage of flight when the velocity of the missile has been reduced almost to the leisurely pace of the steel-jacketed bullet. We can only conjecture as to the withering severity of those earlier stages of the conflict when the

molecular bombardment is so vehement that the exposed surface of the invader is kept in a continuous state of violent vaporization—in short, when the exterior of the dwindling missile is subjected to a condition of continuous or protracted explosion.

This condition of prolonged surfacal explosion quickly dissipates the meteorite unless it is of considerable size. During this stage of the conflict, any train left in the body's wake is believed by the writer to be due to condensation of vaporized material and to ionized particles of the meteorite and of the atmosphere. Later, as the velocity is reduced and denser levels of the atmosphere are encountered, explosive actions are limited to periods of critical temperature and pressure produced by the impacting of air in front of and about the meteorite. During this stage the vaporization is accompanied or replaced by liquefaction and there may occur considerable fracturing. Intermittently violent explosions take place in the dense cushion immediately in front of the speeding missile. These are disruptive and give rise to the many fragments which sometimes arrive as a meteorite shower. It is during this later, less rapid flight that considerable finely divided material escapes volatilization and contributes to the persistent clouds often left in the wake of meteors. These late intermittent explosions are responsible for the flashing so often witnessed near the finish of a large meteor, and recorded in a number of telescopic photographs and also in the photograph shown in Figure 3.

FIGURE 4
A photograph of the sun made with Mr. Charles M. Brown's camera, the same as that used in photographing the moving meteor shown in Fig. 3.

It is to call our attention to the violence of these disruptive forces as indicated by the huge dimensions of the clouds produced and the distance to which detonations are effective, that this paper is presented. Incidentally, it is hoped that the article will emphasize the importance of determining the mass of meteoritic matter which may sometimes be disintegrated in connection with the plunge of a meteorite into the atmosphere.

Secretary's Office: Nininger Laboratory, 1955 Fairfax Street, Denver, Colorado.
Editorial Office: Department of Astronomy, University of California at Los Angeles.

A Small Unexpected Meteor Shower

While studying the sky with the naked eye from the observing deck of the Dearborn Observatory on May 15-16 around midnight, I observed eighteen meteors definitely enough to plot them as shown on the accompanying diagram. Of these, thirteen appear to belong to a small shower, with the radiant very close to Arcturus. All of them were observed within a period of seventy minutes at

the following times: 11:56, 12:01, 12:09, 12:15, 12:27, 12:35, 12:39, 12:40, 12:41, 12:46, 12:55, 1:02, and 1:06, Eastern Standard Time. The meteors which appeared at 12:01, at 12:46, and at 12:55 were considerably brighter than first magnitude.

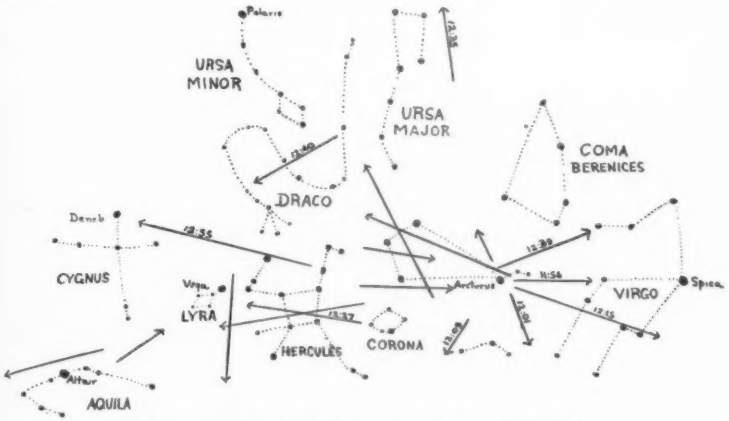


CHART OF METEORS OBSERVED ON MAY 15-16, 1936

The times for some of the meteors are shown on the diagram. A number of others were observed and are plotted, but the time was not determined to greater accuracy than several minutes, and hence their time is not shown.

Five sporadic meteors not belonging to the shower were observed, and are plotted.

HAROLD M. MAYER.

1417 Arthur Avenue, Chicago, Illinois.

Comet Notes

By G. VAN BIESBROECK

COMET PELTIER (1936 *a*). When the previous notes came into the hands of the readers of POPULAR ASTRONOMY the time had been too short to make safe predictions for the ensuing two months concerning this comet. This time these remarks will not be available until most of the appearance is over!

The expectations about this, the first comet of the year, have fully materialized. From an inconspicuous small nebulous object as it was at the time of its discovery by Peltier, it has grown rapidly to naked-eye visibility in the first week of July. Seen in the telescope it then showed a bright stellar nucleus from which emerged a fan-shaped streamer in the direction of the sun. This streamer gradually merged with the head, and in an opposite direction could be seen the tail of more than a degree in length. Figure 1 is reproduced from a 20 minute exposure with the 24-inch reflector on July 12. The photograph records the shape of the head and tail but the material around the nucleus is so bright that the inner details of the head are lost; in Figure 2 I have tried to record the appearance of the sharp nucleus with its vase-shaped streamer opposite to the tail.

Several computers have established the orbit of this comet. The following

elements by A. D. Maxwell, deduced from measures up to June 13 by McLaughlin (Michigan), gave a close approximation to the final parabola:

ELEMENTS (1936.0)

$$
\begin{aligned}
T &= 1936,\ \text{July}\ 8.99068\ \text{U.T.} \\
\omega &= 148^\circ\ 31'\ 44''.5 \\
\Omega &= 133\ \ 59\ \ 05.5 \\
i &= 78\ \ 38\ \ 41.5 \\
q &= 1.1001092
\end{aligned}
$$

FIGURE 1

COMET PELTIER (1936 *a*) ON JULY 12, 1936,
from a 20-minute exposure with the 24-inch Reflector of Yerkes Observatory.

In Figure 3 I have represented the relative positions of the comet, the earth and the sun corresponding to this computed orbit. It will be seen that on August 5 the comet crosses the plane of the earth's orbit from north to south. The nearest approach to the sun occurred on July 9, but after that date the distance from the earth diminished considerably. While the greatest physical activity, especially in the actual development of the tail is to be expected in the middle of July, we earthly observers come so much closer to the comet in the first days of August that its tail will probably subtend an angle of several degrees. At minimum dis-

FIGURE 2

SKETCH OF COMET PELTIER (1936 *a*)

tance from the earth (August 4) the separation is only one-sixth of our distance from the sun. The following ephemeris computed by Dr. Maxwell shows how rapidly the comet will pass out of view for northern observers in the beginning of August.

	α		δ	
0^h U.T.	h	m	°	′
July 31	22	13.5	+25	56
Aug. 1		6.8	19	40
2	21	59.7	12	44
3		52.4	+ 5	7
4		44.8	— 2	56
5		37.0	—11	5
6		29.0	—18	59
7		20.8	—26	20
8		12.4	—32	56
9	21	3.9	—38	43

At that time it will move at the rapid rate of 8° a day from the constellation of Pegasus through Aquarius and Capricornus, but the full moon will hamper the visibility. From my naked-eye estimates the comet reached magnitude $5^M.1$ on July 16. A maximum brightness of third magnitude in the first days of August can therefore safely be predicted. This would be the total light of the comet; the nucleus alone, as seen in a telescope, would appear several magnitudes fainter than a 3^M star. By the middle of August a rapid drop of brightness will set in, but the comet will probably be followed for several months longer with telescopes in the southern hemisphere.

Comparisons of the brightness of the comet with that of neighboring stars

are of great value. When the object is as bright as Peltier's comet, naked-eye estimates are easier and safer than those made with a telescope.

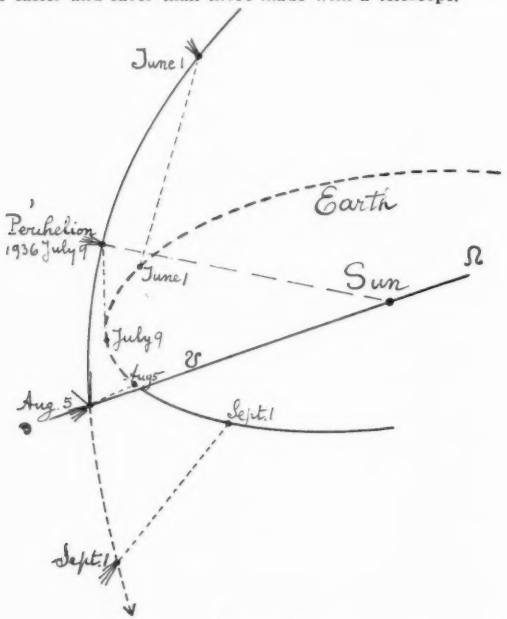


FIGURE 3
ORBIT OF COMET PELTIER (1936 *a*) AND
ORBIT OF THE EARTH

The only other known comet which is now under observation is extremely faint: during June and July COMET VAN BIESBROECK (1935 *d*) was recorded here photographically as a small round coma of magnitude 16. The ephemeris given on page 269 required corrections of —11ˢ and —4′ on July 1; the deviation is small enough so that the following extension can be used without correcting the elements:

	0^h U.T.		α h	m	s	δ °	′
1936	Aug.	8	21	5	23	+51	39.6
		12		10	56	52	7.5
		16		16	28	52	30.7
		20		21	59	52	48.7
		24		27	23	53	2.1
		28		32	36	53	10.9
	Sept.	1		37	34	53	15.4
		5		42	15	53	16.2
		9		46	35	53	13.3
		13		50	32	53	7.1
		17		54	4	52	58.2
		21		57	10	52	46.9
		25	21	59	48	52	33.7
		29	22	1	58	52	18.8
	Oct.	3	22	3	41	+52	2.9

The comet comes to opposition on August 8 and its high declination places it under excellent conditions for northern observers. The duration of visibility will depend on what happens to the intrinsic brightness which dropped so rapidly before perihelion but afterwards remained nearly unchanged at this low level of intensity.

A faint comet with a 7-year period, which has been seen at several returns since its discovery in 1851 by d'Arrest is due in the vicinity of the sun next January. Unfortunately it will then be behind the sun and the only opportunity to locate its presence is several months earlier or several months later. The writer took plates for the object last month in the evening sky but no trace of the comet could be detected at this early date. The following ephemeris is compued by J. T. Foxell and A. E. Levin (*Handbook of the British Astronomical Association* 1936, p. 21):

	0^h U.T.	α h	m	δ °	′	Distance from sun	Distance from earth
1936	Aug 4	13	50.1	+ 7	17	2.14	2.22
	12	13	59.7	5	38	2.09	2.25
	20	14	10.5	3	55	2.03	2.27
	28	14	22.5	2	09	1.97	2.29
	Sept. 5	14	35.7	+ 0	20	1.92	2.30

A slight increase in brightness is to be foreseen but this will be balanced by the lower altitude as the comet moves westward. The poor conditions of visibility make the recovery doubtful.

Williams Bay, Wis., 1936, July 18.

P. S. Comet Kaho-Kosik (1936 *b*).

The second new comet of this year has just been announced. It was found by Kaho at Sappora (Japan) shortly after the sunset on July 17 and independently two days later by Kosik at Tashkent (Siberia). The first position and especially the motion given by the discoverer proved to be considerably in error. But the object was bright enough to be easily picked up and its position was measured at various observatories. The brightness on the first days was given as 5 or 6^M. From the first available data Whipple and Cunningham of the Harvard Observatory computed the following preliminary orbit:

$$\left.\begin{array}{rl} T = & 1936\ \text{July}\ 13.70 \\ \omega = & 40^\circ\ 56' \\ \Omega = & 262\ \ 2 \\ i = & 123\ \ 8 \\ q = & 0.522 \end{array}\right\} \quad 1936.0$$

Ephemeris:

0^h U.T.	h	m	s	°	′	M
July 23	9	51	20	+36	31	6.0
27		50	53	36	56	
31		49	20	37	6	
Aug. 4	9	47	20	+37	7	8.0

The comet was at its brightest at the time of discovery. With increasing distances from the sun and from the earth it is expected to fade rapidly. It has been recorded several times by the writer in the evening sky, showing a sharp nucleus and a bright straight tail a couple of degrees in length. The comet can, however, be seen only for a short time after sunset. The decreasing altitude and the miminution in brightness will shorten the period of visibility.

July 29, 1936.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

New Observers: The following are new observers in the A. A. V. S. O.: A. C. Humbert, Yokohama, Japan; Clarence O. Jensen, San Francisco, California; Othar Kiel, Ronald Peeling, James Rutledge, Wellington Scranton, James Weldy, Mount Union College, Alliance, Ohio; Elmer Kripmeyer, Sharon, Connecticut; and William Loring, Lakeville, Connecticut.

Observations: A list of contributors of observations during the months of May and June is given herewith, stating the approximate number of variables observed and observations which are to appear in the published tables:

Name—	May Vars.	May Obs.	June Vars.	June Obs.
Adamopoulos	12	12	.	.
Ahnert	26	78	23	106
Andrews	.	.	3	5
Armfield	.	.	14	24
Baldwin	52	149	.	.
Ballhausen, Miss	.	.	7	7
Bappu	25	76	29	86
Belsham	.	.	72	74
Blunck	12	16	39	80
Bouton	44	59	47	69
Brocchi	15	30	.	.
Brockmeyer	10	32	6	13
Brown, S. C.	11	11	14	34
Buckstaff	11	31	17	86
Callum	17	24	27	44
Cameron	12	17	9	11
Chandra	102	220	.	.
Christman	32	32	31	31
Cilley	27	48	39	53
Crout	11	13	11	19
Dahm	9	14	14	17
Dalton	5	10	.	.
Dennison	2	2	.	.
Diedrich	8	16	.	.
Doolittle	24	57	9	9
Ellis	42	93	42	93
Ensor	52	112	.	.
Farnsworth, Miss	1	1	.	.
Fish	.	.	3	3
Focas	56	77	.	.
Ford	25	25	.	.
Francis	4	4	.	.
Franklin	15	35	19	19
Friton	.	.	20	58
Gregory	40	66	30	39
Haas, W.	8	39	.	.
Halbach	35	55	45	51
Hamilton	17	56	11	36
Hartmann	127	262	123	288
Hassler	.	.	17	17
Heines	7	19	5	20
Herbig	25	37	35	190
Hiett	11	43	14	51
Hildom, A.	.	.	24	67
Hildom, L.	.	.	9	11
Holt	17	23	.	.
Houghton	77	217	76	207
Houston	10	10	54	164
Howarth	9	10	12	13
Humbert	.	.	2	3
Jensen	2	3	.	.
Jones	99	292	54	158
Keuziah	1	2	5	6
Kiel	3	3	.	.
King	12	19	8	12
Kirkpatrick	10	22	12	40
Kitchens	4	4	6	8
Knott	.	.	7	8
de Kock	31	103	22	83
Koons	.	.	15	15
Kotsakis	32	68	.	.
Kripmeyer	1	1	.	.
Lacchini	24	24	.	.
La Fon	20	20	22	22
Loepfe	1	1	1	1
Loreta	19	52	12	28
Loring	1	1	.	.
Luczka	.	.	10	12
McLeod	35	89	.	.
McNeill	6	18	5	15
Millard	38	75	34	77
Mitchell, R. A.	.	.	1	2
Moore	10	10	8	9
Olcott	.	.	2	2
Peck	.	.	14	69
Peeling	2	2	.	.
Peltier	150	193	160	226
Proctor	.	.	12	12
Purdy	4	4	.	.
Recinsky	13	42	12	39
Richards	.	.	1	1
Rosebrugh	46	69	36	87

Name—	May Vars.	May Obs.	June Vars.	June Obs.	Name—	May Vars.	May Obs.	June Vars.	June Obs.
Roth	3	4	.	.	Smith, F. P.	7	11	12	15
de Roy	8	33	10	67	Smith, F. W.	4	7	10	19
Rutledge	3	3	.	.	Smith, L.	21	22	1	3
Salanave	19	22	7	12	Smith, L. L.	3	3	.	.
Scanlon	28	30	.	.	Thomas, Mrs.	.	.	1	5
Schattle	.	.	5	35	Thorndike	7	8	1	8
Schmidt	3	3	.	.	Treadwell	7	23	7	25
Scranton	3	3	.	.	Watson	32	72	.	.
Seely	3	7	7	23	Webb	40	54	38	58
Shinkfield	24	45	21	34	Weiss	1	4	.	.
Shultz, Miss	15	15	13	13	Weldy	6	9	.	.
Sill	14	22	5	5	Woods	26	52	17	41

Nova Lacertae (221255): This naked-eye nova, at first referred to as Nova Cephei, was discovered independently by several observers on June 18, 1936. Like Nova Aquilae, 1918, it was nearly coincident with a total solar eclipse, the eclipse occurring a few hours after the Nova was discovered, while at the time of the appearance of Nova Aquilae, the eclipse occurred some hours earlier. Although

PROVISIONAL LIGHT CURVE OF NOVA LACERTAE

the recent Nova was first seen in America by Mr. L. C. Peltier, of Delphos, Ohio, later advice indicated its earlier discovery by several European observers—they having the advantage of earlier hours of darkness. The Nova was probably first seen by Dr. W. Zonn, a member of the Polish Solar Eclipse Expedition to Keratea, near Athens, Greece. The time of discovery is given as June 18, at about nineteen and a half hours, Universal Time, and the magnitude was estimated as slightly fainter than η Cephei, or $3^{M}.4$ on the Harvard Photovisual system. It was discovered also by Messrs. A. V. Nielsen, Aarhus, Denmark; E. Loreta, Bologna, Italy; Dr. C. Hoffmeister, Sonnenberg, Germany; L. M. Upjohn, Kalamazoo, Michigan; N. Guriev, Stalinabad, U. S. S. R.; and at Heidel-

berg, Germany. Doubtless, it was also independently discovered by numerous others. By a strange coincidence, Loreta and Peltier were co-discoverers of the second outburst in Nova (RS) Ophiuchi, in August, 1933.

The Nova brightened approximately half a magnitude between the times of discovery in Greece and in America. It was still brighter on June 19 and reached its maximum at nearly second magnitude about June 20, Greenwich Noon. In its general light characteristics, Nova Lacertae closely resembles Nova Aquilae, 1918. It is apparent that Nova Lacertae rose rapidly, and, according to photographic evidence, from approximately the fifteenth magnitude. The decline from maximum has been somewhat rapid, as was that of Nova Aquilae, with a gradual retardation in recent days. If Nova Lacertae continues to follow its prototype, we should oon expect a period of oscillations to set in.

Observations have been received to date for every night except those of July 3 and 11. A table and curve containing observational facts, are given herewith. Charts giving comparison stars and their magnitudes, on the photovisual system, down to the tenth magnitude, have been issued to observers. Copies of these can be obtained by communicating with the Recorder, A. A. V. S. O.

NOVA LACERTAE

June	J.D. 242	No. Obs.	Mean Mag.	July	J.D. 242	No. Obs.	Mean Mag.
18	8338.4	15	3.36	1	8351.6	6	5.18
19	39.7	37	2.35	2	52.7	3	5.37
20	40.6	20	2.32	3	53.	.	..
21	41.7	32	2.82	4	54.7	3	5.60
22	42.6	20	3.36	5	55.6	2	5.55
23	43.8	2	3.55	6	56.6	6	5.65
24	44.6	7	3.94	7	57.6	2	5.85
25	45.6	19	4.03	8	58.6	6	5.82
26	46.7	9	4.36	9	59.6	1	6.0
27	47.7	11	4.64	10	60.6	2	5.95
28	48.7	16	4.79	11	61.	.	..
29	49.7	1	5.0	12	62.7	1	6.3
30	50.7	7	5.04	13	63.7	1	6.3
				14	64.6	2	6.30

Comments on Variables: CY Aquarii: The shortest-period variable known to exist, CY Aquarii, period $87^m\ 54^s$, reveals a color range difference quite consistent with that found for regular Cepheids of much longer period. The range in blue light is 1.6 times as large as that in red light, which compares favorably with a factor of 1.7 for other Cepheids in general. During the light variation, the spectral change is from Class B8 to A3. The light curve closely resembles Bailey's Cluster Type "b", in which the descent from maximum to minimum is gradual with no indication of flatness at any one point. No evidence of a change in period exists from the observations so far made.

Zeta Aurigae: The long-period eclipsing variable ζ Aurigae (period 972 days) is found to have the greatest difference in radii between components of all known eclipsing stars. Recent published results confirm the adopted value derived at Harvard, namely, a ratio of 0.03, or the diameter of the larger star thirty-three times that of the smaller star. In fact, just before and after eclipse, the smaller star appears to be visible through the outer and thinner portions of the atmosphere of the larger star.

RY Scuti: The variable star, RY Scuti, listed by Prager as of Irregular type has been found by Dr. S. Gaposchkin to be a perfectly regular variable of

the eclipsing type with a period of $11^d.2$. n fact, RY Scuti is almost a perfect counterpart of β Lyrae, when type of spectrum, form of light curve, and length of period are considered. The spectrum is even more peculiar than that of β Lyrae, which has been considered one of the most complicated of all eclipsing systems.

WILLIAM TYLER OLCOTT: Variable Star Astronomy, especially the observational work, suffered a severe loss in the death, on July 6, of William Tyler Olcott, co-founder in 1911, with Edward C. Pickering and Herbert C. Wilson, of the American Association of Variable Star Observers, and its Secretary for nearly a quarter of a century.

Born on January 11, 1873, in Chicago, Illinois, Mr. Olcott spent most of his life in Norwich, Connecticut, where he maintained one of the best amateur observatories to be found in America. Besides his three-inch portable glass, for casual observations of bright variables, he possessed a well-equipped five-inch telescope in a little dome on the top of his home.

It is to Olcott, more than to any other individual, that the Association owes its birth and, in its earlier years, its growth to an organization of world-wide influence and reputation. Upon his shoulders rested the responsibility for the success of the Association; because in the formative years, as Secretary, he not only prepared thousands of charts for use by the observers but compiled the data for publication in POPULAR ASTRONOMY and also maintained a voluminous correspondence, which at that time was most essential to the holding together of the widely separated interests of the members.

Olcott's interest in variable stars can be attributed partly to his desire to put to practical use a very complete knowledge of the constellations. He began his variable star observing in January, 1910, shortly after a visit to Harvard Observatory, where he saw on display the numerous plottings of light curves depicting the vagaries of many types of variable stars.

Although educated at Trinity College, at Hartford, Connecticut, and trained for the legal profession, he never practiced law, but instead, devoted his life to writing books dealing with the stars, with a view to interesting the "man of the street" in the wonders of the starry firmament. He was the author of half a dozen books and it was through the medium of these books that the A. A. V. S. O. secured many of its best variable star observers.

At the May meeting of the A. A. V. S. O., Secretary Olcott was voted the Third Merit Award of the Association, to be presented on the occasion of the Twenty-Fifth Anniversary of the founding of the Association and of his Secretaryship.

Mr. Olcott was active to the end. His interest in the A. A. V. S. O. never lagged and at the time of his death, he had practically completed a book dealing with the Southern Constellations, a very much needed volume.

On the foundations so firmly laid by Secretary Olcott, the A. A. V. S. O. and variable star observing by amateurs will doubtless proceed uninterrupted but, nevertheless, the active guidance of William Tyler Olcott will be sorely missed.

July 16, 1936.

Notes from Amateurs

A Solar Projection Screen for the Amateur

One of the very interesting branches of astronomical study for the amateur is that of the sun-spots, and a very safe method of observation is that of pro-

jection on a solar screen, especially the type prescribed by the British Astronomical Association. The writer made one of these with little difficulty, added a few minor improvements, and found the cost within reach of any amateur. It has worked so successfully and is so interesting that it became the desire of the writer to share it with his fellow amateurs, so that they too, might not only add an accessory to their telescope and have the fun of making it, but that they might also enjoy following a cycle of sun-spots through its course from maximum to minimum and its reversal.

FIGURE 1
CLOSE VIEW OF FRAME AND SCREEN.

The screen here described (Figure 1) was designed for a 3-inch refractor telescope; lightness and simplicity were the main considerations. The frame was made of square brass tubing, obtainable in any good hardware store; the screen drawing board itself, of sheet aluminum, and the cross brace of southern dogwood, which has an excellent close grain and finishes beautifully, although any good hard wood will do. Additional tubing was obtained just large enough to slide over the frame tubing and from this right-angle brackets were made, which hold the aluminum drawing board on the frame itself. A unique method was accidentally discovered for fastening the drawing board on to the brackets. After

cutting down the brackets for bending, enough material was left so as to form a recess for the small strips of brass screwed on to the board, the depth of this recess, as can readily be seen, depends on the thickness of the brass strips. This made an excellent method for fastening as there is absolutely no play and at the same time good rigidity. A steel spring was placed inside the bracket to take up whatever play there might be here, and the bracket itself, after the proper focus was found, was held in position on the frame and also the spring by small knurled thumb screws. Thumb screws were also found for fastening the drawing board on the brackets by placing a flat-headed machine screw through the drawing board and countersinking the hole through which they passed.

Two thumb screws were also obtained for clamping the brace on the telescope tube, the square nuts for these screws were tightly imbedded in the wood and served their purpose splendidly. The recess for the telescope tube was lined with felt and a neat way for securing the ends of the felt strips was to make a saw cut at the end of each horizontal recess and forcing the ends of the felt in the saw cuts. The open ends of the frame were closed with little blocks of hard wood and the two mitred joints were welded together with silver solder, although the writer believes that a right-angle elbow, cut to fit the inside of the tubing and secured with countersunk screws, would make a more satisfactory joint, the welding process having a tendency to warp the frame slightly upon cooling. A scale was scribed on the frame and found to be very useful, the work was done with a scribing tool and the numbers were stamped in. For the screen itself several kinds of cardboard were experimented with but the best found was the white with a hard smooth surface such as is used for small window signs. Squares of this were cut to fit the drawing board and held in place with clips which can be purchased in one of the local five and ten cent stores. A cardboard shield is used ahead of screen for obscuring direct sunlight. On these squares, circles were drawn, 15 cm in diameter and the image of the sun was made to fill this circle, (15 cm being the proper diameter for use with a 3-inch refracting telescope). The image was then oriented by bringing a spot to the east limb and letting it run through the circle of the drawing sheet. The place of entrance and the place of leaving were then noted and marked and the line of connection of the two places gave the direction of the daily movement (east-west direction) on the drawing. The image was again made to fill the circle and the spots were then quickly outlined with pencil and the faculae with blue crayon, and, when finished, studied, and counted at leisure. The projection screen and frame were, however, primarily made for use with Stonyhurst sun discs which are fully described in the *Memoirs of the British Astronomical Association*, Vol. XXXIII, Part 2, pp. 74-78, to which the reader is referred.

The writer is indebted to Professor Anne S. Young, Mount Holyoke College, for instructions on the use of solar discs and to Professor J. Ernest G. Yalden of Leonia, New Jersey, whose suggestion it was to pass along to fellow amateurs through POPULAR ASTRONOMY an article about the solar projection screen and to POPULAR ASTRONOMY itself for publishing the article.

The writer would be pleased to answer in detail any questions which might arise in the minds of those who may undertake to construct a solar projection screen similar to he one here described.

NEAL J. HEINES.

560 Broadway, Paterson, New Jersey.

Cleveland Astronomical Society

The summer home of Sheldon Towson at Gates Mills was the scene of our June meeting. Picnic lunch with coffee served to get our astronomers in the right frame of mind for the evening program.

The "skipper" Captain Towson, (owner of a fine yacht), with Mrs. Towson, saw to it that we were all well taken care of and this proved to be one of our most successful gatherings.

William Buttles and wife were in Cleveland the latter part of the month. He is well known as the founder of "Astrolab," the group which has contributed many new developments in astronomical apparatus. They were returning from an eastern science meeting and renewed old friendships with the author and wife at our home. Later in the day they visited the great plant of Warner & Swasey where they were escorted around by Mr. Burrell, chief engineer. They stopped at Delphos, Ohio, to see Leslie Peltier at his observatory. He has another comet to his credit now in addition to his past contributions to science.

The latest development shown by Buttles is a new eyepiece with a remarkably large flat field. It consists of achromatic lenses fitted into a 2-inch tube and with a perfect large eye cup covering the entire eye and excluding all extraneous light. The cup is of a new material which comes in beautiful colors and is comfortable even in zero weather.

We discussed all aluminum telescopes. Mr. Buttles is the originator of the famous polar bowl aluminum mounting for reflectors, while the author specializes in aluminum mountings for refractors only. When we get together the time is always too short to discuss all the new devices and fitments which we should like to produce.

Prospective new members are asked to get in touch with Mr. Gordon at 1599 Union Trust Building, Cleveland. A splendid winter program is in preparation by our president, Dr. J. J. Nassau, and the committee.

Don H. Johnston, *Recording Secretary.*

14 Lincoln Drive, Cleveland, Ohio.

Amateur Telescope Makers of San Francisco

The meetings of this group are entirely informal and no very definite program is followed. At the meeting of May 11, Mr. J. B. Duryea gave an interesting and instructive talk on the use of the telescope by the amateur. He endeavored to impress the members with the idea that there was great satisfaction in the using of a telescope as well as in the making of it, a fact which is sometimes overlooked. The meeting on July 10 was held at the home of one of the members, Mr. W. M. Grant. At this time Mr. Grant demonstrated the apparatus and method which he had developed for aluminizing mirrors. His equipment enables him to aluminize mirrors as large as fourteen inches in diameter. Dr. F .W. Epley gave an interesting account of a recent visit to Pasadena where he witnessed the work in progress relating to the 200-inch mirror. The next meeting is scheduled for August 14, at which time Dr. P. Spouse will exhibit and explain a new star chart which he has devised.

Mr. F. J. Corrigan is the secretary of this group.

Astronomical Society of Nevada

The Astronomical Society of Nevada held its second annual Hill-Top Telescope Meeting in Reno on the evening of June 26.

Dr. Robert E. Smith of Sacramento was present with his new 8-inch New-

tonian reflector. The mirror of this telescope, which gave remarkable definition, was made under the expert guidance of a member of the Society, Mr. Carl E. Wells of Roseville, California. Several other telescopes were supplied by local amateurs.

Peltier's comet, the moon, Jupiter, and the Great Cluster in Hercules were the principal objects observed. About one hundred people, members of the Society and their guests, enjoyed an evening out under the stars. A feature of the evening was an illuminated bulletin board showing photographs of the objects observed, a chart of the heavens, and charts of the position of Peltier's comet and of Nova Cephei.

The officers of the Society are: G. B. Blair, President, Rader L. Thompson, Vice-President, John E. Humphrey, Box 1429, Reno, Nevada, Secretary-Treasurer, and Chas. H. Gorman, Chairman of the Program Committee.

Maine Astronomical Society.—The most recent astronomical society of amateurs that has been reported to us is the one by the above name and is located at Portland, Maine. The organization meeting was held on June 26, at which Mr. Robert M. Dole was elected president and Dr. Wm. L. Holt, secretary.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editors may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

On the Rotation of the Sun

It is a well known fact that the period of rotation of the visible surface of the sun varies with the latitude and that the period is shortest at the sun's equator, gradually becoming longer as the poles are approached. The same phenomenon is observed in the case of certain planets. As yet no explanation of the cause of this strange fact has been accepted, generally, as being correct.

There is one very simple explanation which, as far as the writer knows, has never been suggested, but which he believes is worthy of serious consideration. It is as follows:

The centrifugal force acting on any particle or mass which is rotating around a point such as the centre of the sun varies directly as the square of the velocity and inversely as the radius.

It is highly probable that the visible surface of the sun is gaseous and that what we see when looking at the sun is a mass of incandescent gases. It is also practically certain that these gases are in constant turmoil so that all of the gases, even in a given latitude, are not rotating around the axis of the sun at the same velocity.

Every mass of gases rotating around the axis of the sun in a period equal to the average for the latitude in which the mass of gas is located would be acted on by a certain definite centrifugal force tending to pull it outward and away from the axis. Any mass of gas which, for any reason, happened to be traveling around the axis at a speed higher than the average in that latitude would be acted upon

by a centrifugal force greater than the centrifugal force acting upon the average mass of gases in that latitude. Any mass which happened to be rotating less rapidly than the average in that latitude would be acted upon by a centrifugal force weaker than that acting upon the average mass in that latitude. There would thus be a distinct tendency for any mass of gas to force itself outward and away from the axis if it were by any means given an impetus which caused it to rotate more rapidly than the average mass in the same latitude.

The gases which have this higher speed of rotation would thus tend to become the outer and therefore the visible gases of the sun while the gases with slower speed of rotation would tend to settle down and become invisible.

In order to visualize more clearly how the effect described above might take place it might not be out of order to speculate a little as to what is taking place on the sun and how the phenomenon under consideration would be caused.

There is little doubt but that at times huge masses of gases are shot upward and outward from the sun at terrific velocities and to tremendous distances. As these gases rise rapidly the pressure to which they would be subjected would suddenly decrease and they would expand with explosive violence in all directions, north, south, east, and west with equal velocity relatively to the center of the expanding mass.

Imagine such an eruption on the equator of the sun which we will say is traveling in a west to east direction with a velocity of about 6,700 feet per second. The gases in the center would continue with this same velocity but the gases surrounding the center would expand outward in every direction, north, south, east, and west, due to expansion. Suppose that this velocity imparted by expansion became 6,700 feet per second. Then the masses of gas which expanded to the westward would actually cease to rotate around the axis of the sun. The masses which expanded to the eastward would actually be rotating about the axis of the sun at twice the original velocity. Neglecting the effect of the increase in distance from the axis of rotation the mass which was shot eastward would acquire four times the centrifugal force which it originally had, while the centrifugal force acting on the mass shot westward would become zero.

It is not unreasonable to suppose that the gases which were shot westward would act as though they were heavier than the average and would descend toward the axis, where they would come into contact with other gases traveling at various velocities and in various directions but whose average speed and direction would be the observed rotation at the equator. Such gases would in time be speeded up to conform to this average speed. The gases shot eastward would act as though they were lighter than the average and would tend to rise and become part of the visible surface of the sun.

Thus the visible surface of the sun would consist of masses of gases which were traveling in the direction of rotation at velocities higher than that of the great bulk of the sun lying beneath them and closer to the axis. At the poles this effect would of course be zero because the centrifugal force would be the same regardless of direction. In latitudes between the equator and the poles the effect would become less than at the equator as the pole was approached.

It is true that the forces causing this supposed elevation or depression of gases is not great but neither are the forces which create the tides on earth, and yet the effects of the tidal forces are visible.

The planets presumably do not have the intense surface activity which is observed on the sun but the continuously changing surface of Jupiter, at least, where

the same phenomenon is apparent, indicates a high degree of activity, making possible this effect.

D. W. LONGFELLOW.

Elk River, Minnesota.

Asteroid Notes

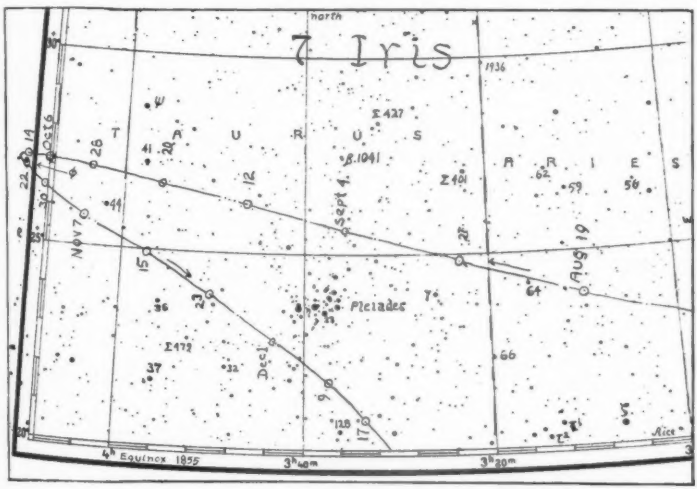
By HUGH S. RICE

PALLAS, CERES, AND AQUITANIA

We have received reports from Mr. Morgan Sanders, energetic observer of Baltimore, that he has had asteroid 2 Pallas under observation, using previous charts published, on 51 nights, from February to July; but now at last the object is getting too faint for small telescopes. The interesting part was the close approach to the star Arcturus on April 13. Giant Ceres has likewise been under careful scrutiny by Mr. Sanders, and in 74 observations made to date is holding to its charted path (which extends to mid-August. It is now on its forward course within the diamond-shaped figure of Libra. A much more elusive object indeed is 387 Aquitania, whose ephemeris was given, but observers have reported extensive search for it, covering a wide zone, without success. Apparently it is not keeping to its predicted path among the stars.

7 IRIS

In this issue we reproduce a diagram of the apparent path of 7 Iris. This minor planet was discovered on August 13, 1847, by Hind in England. At the



time of discovery it was of 10th magnitude. This discovery was made "after many months' exploration," (as Agnes Clerke expressed it) at the observatory of Mr. Bishop in Regent's Park. Various orbits for Iris were computed by investigators in the early days. In 1888-89 Sir David Gill, the greatest Scottish astronomer of his generation according to Hector Macpherson, attempted to use this planet for the determination of solar parallax. Eros now, however, is used for such purpose. Gill found the ephemerides of Iris not very exact for this work,

the incorrect mass of Jupiter having been used in some of the early work, the perturbations were not accurately known. Medern computation has so improved the results by having better observing data with which to work that the orbit of Iris can now be computed accurately.

We mention Iris because it is the brightest convenient planetoid to observe, covering the entire period of this issue. The opposition date is November 13, and the Astronomisches Rechen-Institut computations cover about six weeks around that date. Irving Meyer, of Rutherford, N. J., has computed places for this planet, that extend the ephemeris from August 4 to December 18. The magnitude range is from $8^{M}.3$ on August 4 to $6^{M}.8$ at opposition, decreasing after that. The opposition magnitude this year is much brighter than the average, which is $8^{M}.4$.

Our plotting for Iris shows it for several weeks in Aries and Taurus. This plotting was made on a corner of a Bayer-Graff chart of the region, and the scale is considerably smaller than in previous diagrams, in order to include several months' path. In its apparent path, it will be seen to travel about the Pleiades. In October it makes a neat turn around ϕ Tauri. Then, an observer should be able to make a record for himself by picking up the planet in a very short time. The smallest stars on the chart are somewhat below 9th magnitude. 7 has already been observed with a 12-inch telescope, and found to be following its predicted path. It needs early-morning observing in August, but by October its position will have become more convenient.

New Names

In 1932 K. Reinmuth discovered an asteroid, which until this year was thought to approach the earth nearer than any other known planet. It carried the temporary designation "Reinmuth object" or number 1932 HA; it has now received as its permanent name Apollo. It will be recalled that the "Delporte object" of 1932 EA_1 was named Amor. The asteroid of closest approach known today, number 1936 CA, also discovered by Delporte, has been given the name Adonis. However, the general news items of this record-breaking asteroid called it Anteros. The reason for the discrepancy in these names we have yet to discover.

Hayden Planetarium, American Museum of Natural History,
New York City, July 23, 1936.

General Notes

Dr. A. Kopff, director of the Rechen-Institut at Berlin-Dahlem, delivered the George Darwin Lecture at a meeting of the Royal Astronomical Society on June 10. His subject was "Star Catalogues, especially those of Fundamental Character."

Mr. William Tyler Olcott, well known for his constructive work as an amateur astronomer and for his writing of books upon astronomical subjects, died suddenly on July 6 while enjoying a vacation at Lake Sunapee, New Hampshire. A brief mention of his activities is to be found on page 397 of this issue, and a more extended account, written by his intimate friend for more than a quarter of a century, Mr. David B. Pickering, will be published in the October issue.

Dr. Anne S. Young, for thirty-seven years Director of the John Payson Williston Observatory of Mount Holyoke College, became an emeritus professor on July 1. Dr. Alice H. Farnsworth, who has been Miss Young's associate for a number of years, has been appointed as her successor.

Miss Young's new address will be 106 13th Street, Winona Lake, Indiana.

Dr. John A. Miller, professor of mathematics and astronomy in Swarthmore College since 1906 and director of the Sproul Observatory of Swarthmore College since 1911, tendered his resignation from both these offices on February 1, 1936. In accepting this resignation the Board of Managers of the College elevated him to the position of emeritus professor and director, and placed a room in the Observatory and the services of a computer and secretary at his disposal. In addition to the useful and extensive work of the Sproul Observatory, Dr. Miller has successfully observed a large number of total eclipses of the sun. His numerous friends wish for him continued good health for many years to be devoted more exclusively to his favorite science.

Simon Newcomb in the Hall of Fame.—The ceremony of the placing of a bust of Simon Newcomb in the Hall of Fame at University Heights, New York City, occurred on May 26, 1936. The bronze bust was the gift of Dr. Ambrose Swasey, and the formal presentation of it was made by Dr. Harlow Shapley. Mrs. Emily Newcomb Wilson, a daughter of Simon Newcomb was present and assisted in the unveiling. A tribute to the memory of the great scientist was given by Dr. W. W. Campbell. (A biographical sketch and summary of the astronomical work of Simon Newcomb will appear in this magazine in the near future.)

At the same time a bust of William Penn was unveiled, and one of Grover Cleveland is to be unveiled next year, which is the centenary of his birth. There will then be a total of seventy-two. Additions are made at five-year intervals.

Solar Eclipse of June 19.—No direct reports have been received by us from the several eclipse expeditions. From press accounts and other indirect information, we learn that conditions at the time of the eclipse were unusually favorable to the programs of the numerous parties. We hope to have the opportunity of publishing reports of some of the stations later.

American Astronomical Society.—The Society will hold its fifty-sixth meeting as the guest of Harvard University, September 2-5, 1936, in connection with the Harvard Tercentenary Conference of Arts and Sciences. Two sections in the symposium on the Physical Sciences—section P-2 Astrophysics, section P-3, Cosmogony—form a part of the program of the Society also, and members of the Society will be admitted to these sections without applying for membership in the Conference. Such membership is required, however, for attendance at any of the other sections.

September 3, 2:00 P.M., Conference Section, Astrophysics. The principal addresses will be "The Temperature Scale of the Stars," by Professor Antonie Pannekoek; and "The Masses of the Stars," by Professor Henry Norris Russell. Short invited remarks will follow.

September 4, 2:30 P.M., Conference Section, Cosmogony. Professor Tullio Levi-Civita will speak on "The Astronomical Consequences of the Relativistic Problem of Several Bodies"; and Sir Arthur Eddington on "Cosmical Constants and the Recession of the Nebulae." Again there will be invited remarks.

The morning session on Friday, September 4, will be devoted entirely to

papers submitted by the Harvard Observatory staff. Mr. and Mrs. Shapley will entertain the Society at a lawn party on Thursday afternoon at the Observatory Residence; the Society dinner will be held on Friday evening; and on Saturday the Society will take its luncheon to Oak Ridge.

Rooms will be provided without charge by Harvard University for members of the Society and their families. They are students' rooms in the Yard dormitories. They may be occupied from Wednesday to Sunday (September 2-6). Application for rooms should be made at a reasonably early date to Miss Frances W. Wright, Harvard College Observatory, Cambridge, Massachusetts. The Commander and Continental are very satisfactory hostelries, convenient to the Observatory and to Harvard Yard.

RAYMOND S. DUGAN, *Secretary.*

Princeton University Observatory, Princeton, New Jersey, May 29, 1936.

Correction.—An erroneous replacement of a line was made after the June-July issue was on the press. On page 311 of that issue, the first line of text under Figure 3 should be

The observations in 1934 were made without reducing the light of ζ

The line that is there is seen to be the same line as the first line of the following paragraph except for the comma at the end which, indeed, was the cause of the error.

Book Reviews

Astronomy, by Dr. A. M. Harding. (Garden Publishing Company, Garden City, New York. $1.98.)

This astronomy comes to the reader with an attractively colored protective paper cover on the front face of which are two very significant statements: "The Splendor of the Heavens Brought Down to Earth" and "The fascinating story of the sun, the moon, and the stars, written so that everyone can understand it and illustrated with many beautiful photographs and diagrams."

The reader's interest is awakened and kept alive by the chapter and subject headings. The chapters and titles are: Chapter I, Our Flying World; Chapter II, The Sun and His Realm; Chapter III, Other Worlds Than Ours; Chapter IV, Our Lunar Companion; Chapter V, Signs and Wonders; Chapter VI, The Story of the Stars; Chapter VII, The Depths of Space; and Chapter VIII, An Astronomer Looks at his Universe.

Turning the pages one finds many of the pictures usually appearing in textbooks on astronomy showing views of the planets, the moon, the sun, nebulas, comets, star-clouds, etc. Several of the diagrams deserve special mention. The one (p. 60) of an express train traveling from the sun to the earth, the one (p. 63) showing an airplane "flying" from the earth to the sun, and the one (p. 78) representing the flights of radio messages from a terrestrial announcer to listeners on some of the celestial bodies, these impress one with the enormous distances separating the astronomical bodies. The drawings (p. 83) showing how gravity affects our "lifting" and "jumping" when stationed on different bodies probably give to the "average" person a more lasting impression than would the mere statement of the facts. The drawings (p. 186) showing how the same crescent moon is tilt-

ed to observers at various points of the earth's surface, and the diagrams accompanying the subject of eclipses are all good. The first drawing (p. 1) taxes the imagination, but one gets the idea of a ball in motion.

In the 416 pages Dr. Harding has not merely given the astronomical facts relating to the earth and all celestial bodies, but he has given much of the history many legends from mythology, and even a number of "jokes" relating to the topics treated. The reader is not required to labor through technical considerations of right ascension and declination, parallax, equation of time, laws of spectrum analysis, aberration, precession, eclipses, etc. The main facts are given and in some cases there are simple discussions "written so that every one can understand." The writer has anticipated and answered many of the questions that are asked every day by students of elementary astronomy and by others. He has made reading easier by using "nebulas" and "novas" the plural forms of nebula and nova, respectively.

The foregoing are only a few of the many good features of the book. Naturally one would expect to find errors in a first print and we find several misspelled words and in one case a word repeated. We read about the sun's "disc" on page 96 yet we meet the word "disk" elsewhere. Some erroneous statements appear such as on page 219, line 1, where we read that the densities of the planets are "in most cases greater than that of the earth," and near the bottom of page 316 the Hercules cluster is called an "open" cluster, although it is correctly referred to elsewhere as a globular cluster. The inquisitive reader would wonder how "if it (Lexell's comet) had weighed anything," (p. 224), "It would take at least a million comets as heavy as Lexell's comet to weigh as much as the earth." The statements concerning Bode's Law (p. 75) and the number of constellations (p. 249) are not in agreement with our present-day textbooks.

The points covered in the preceding paragraph need not materially detract from the value of the book. The newspapers, the magazines, and the radio have created a keen interest in and a demand for popular treatments of astronomical subjects, and whether possessing little or no knowledge of astronomy, or being well versed in it, the reader—layman or student—will spend many pleasant and profitable hours reading Dr. Harding's Astronomy. And the reading will bring about a re-evaluation of one's place in the universe so that he exclaims with the writer "What a loss in dignity! What a gain in grandeur!"

University of Kentucky. H. H. Downing.

Astronomy Club Bulletin is the title given to a collection of mimeographed sheets issued by the Saint Lawrence Astronomy Club at Saint Lawrence University, Canton, New York. The collection issued in April consists of twenty pages and comprises Nos. 1, 4, 5, 6 of Volume I. It contains a number of items interesting to amateurs in astronomy. There are several charts showing individual constellation configurations of the stars with comments designed to aid the beginner in identifying them. A publication such as this indicates a lively interest on the part of the members of the club.

Junior Astronomy News for May, 1936, issued by the Junior Astronomy Club at the Hayden Planetarium, New York City, as usual contains a number of timely and well-written astronomical articles. On the front cover is found an imaginary representation of a large meteor falling upon the tundra of Siberia. This thought is prompted by the expedition undertaken by Dr. Clyde Fisher for the purpose of studying the region of the reported meteoric fall of June 30, 1908.

POPULAR ASTRONOMY

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